Strategic Review of SESSF Monitoring and Assessment

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Table of Contents

List of Figures

List of Tables

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1. Summary

1.1. Background

The Southern and Eastern Scalefish and Shark Fishery (SESSF) is a multi-species, multi-gear, multi-jurisdictional Commonwealth fishery. It is a fishery of substantial economic and social importance to Australia, as a key provider of high quality fish products to Australian markets. More than 600 species are caught or interacted with, including bycatch (discards) and byproduct (minor commercial) species. Commercially-important species targeted in the SESSF include 34 species which are managed under Total Allowable Catches (TACs). TACs are periodically adjusted by the management agency, the Australian Fisheries Management Authority (AFMA), in response to biomass estimates, or proxies thereof, derived from monitoring and assessment activities. These include the collection of data (principally catch and effort) from fisher records (log books and catch disposal records). Additional information is derived from fishery-independent surveys (FIS), on board observers, port sampling and crew sampling (e.g. biological data), and occasional dedicated research programs. Additional management requirements reflecting the *Commonwealth Harvest Strategy Policy 2007*, the *Commonwealth Policy on Fisheries Bycatch 2000*, and the *Environment Protection and Biodiversity Conservation* (EPBC) Act 1999 require additional information from monitoring and assessment activity. It is now a requirement to record any impacts on bycatch; byproduct; and threatened, endangered and protected species (e.g. seals, seabirds, dolphins). Most monitoring and assessment costs are borne by the Industry (those licencees holding statutory fishing rights to participate in the SESSF). Recently, expanding monitoring and assessment activity has coincided with decreasing commercial returns (primarily as a result of falling prices for some commercial species and the failure to fully catch TACs). It is important that future monitoring and assessment activity applicable to the SESSF is cost-effective for all sectors. This review evaluates existing monitoring and assessment arrangements and provides recommendations on future monitoring and assessment to cost-effectively meet management and legislative requirements.

1.2. Objectives

The overall purpose of the SESSF Monitoring and Assessment Review Project (SMARP) was to conduct an extensive review of the monitoring and assessment required to meet the objectives of fisheries management. including the revised Commonwealth Harvest Strategy Policy (HSP) and Fisheries Bycatch Policy, and identify and recommend cost-effective monitoring and assessment options that meet these needs.

To achieve this goal, the project had the following objectives:

1. In consultation with the project Reference Group, SESSF Resource Assessment Group (SESSFRAG) and South East Management Advisory Committee (SEMAC), identify priorities, key concerns, perceived shortcomings and opportunities for improvement in monitoring and assessment arrangements for the SESSF.
2. Review the efficiency and cost-effectiveness of current monitoring, assessment and management arrangements for the SESSF, and the extent to which they meet the requirements of fisheries policies, including implications of recommendations arising from the reviews of the Commonwealth Fisheries: Legislation, Policy and Management, Commonwealth Fisheries Harvest Strategy Policy and Guidelines and Commonwealth Policy on Fisheries Bycatch.
3. Review recent relevant regional and international fishery developments to identify options for improvement in the efficiency and cost-effectiveness of monitoring, assessment and management arrangements for the SESSF and critically review the design and performance of the multi-species fishery independent trawl surveys (FIS).

4. Conduct a qualitative assessment of a suite of rationalised monitoring and assessment options currently against reference points implied under the revised fishery policies for target, byproduct, bycatch and Threatened, Endangered and Protected (TEP) species groups.
5. Using the results of the objectives above, provide a report with recommendations for revised, implementable and cost-effective monitoring, assessment and management arrangements for the SESSF.

1.3. Project Reviews

The review follows extensive stakeholder consultation; independent assessment of the current monitoring, assessment and management arrangements for the SESSF; evaluation of similar monitoring and assessment activities in other countries (including electronic monitoring and fishery-independent surveys); and a qualitative assessment of the monitoring and assessment needs arising from imposition of Ecosystem Based Fisheries Management (EBFM). Various in-depth reviews were undertaken as part of this project.

1. To determine fishery priorities, an extensive review of the current and proposed legislation and policies was conducted and implications of the underlying data, assessment and reporting requirements was assessed.
2. Stakeholder views on priorities and opportunities for improvement in SESSF monitoring and assessment were canvassed during two focussed workshops involving key stakeholders, who constituted a Reference Group for the project.
3. A wide range of monitoring tools is used in the fishery, shown in the table below. Acronyms used in the table are as follows: electronic logbooks (E-logs), Catch Disposal Records (CDRs), Vessel Monitoring System (VMS), Electronic Monitoring System (EMS).

   The existing data collection and monitoring arrangements for the fishery were documented and analysed for each data source and type, evaluating frequency of collection, and data entry and transfer protocols. Contracted external reviews were conducted on the fishery independent multi-species trawl surveys carried out in the SESSF.

Logbook / E-logs / CDRs • Catch and effort data • Verified landings • State fishery landings • Recreational catch • TEP interactions	**Dedicated research projects** • Biology / stock structure • Population dynamics • Survey of fishing gears • Reference points • Oceanography	**Licencing and Compliance** • Owner / vessel registry • Concessions • VMS • EMS
Observer data • Catch composition • Length Frequency • Age data • TEP Interaction	**Fishery Independent Surveys** • Abundance Index • Catch composition • Length Frequency • Age data • Bycatch interaction	**Industry data** • Quota trading • Economics • Length frequencies • Markets

4. The history of stock assessment in the SESSF is described together with the ongoing process of revision and improvements leading to the current situation. Tiered assessment approaches have been developed depending on information availability for each stock, and applied to stocks in the SESSF for many years. Historically, the choice of assessment type has been determined based on whether it was a quota species, the economic importance of the species and whether it is data rich or data poor. Typically, Tier 1 (and Tier 0) assessments have been performed on economically important quota species and Tier 3 and Tier 4 assessments were

performed on other quota species because they were largely seen as byproduct species or the data was either not available or was not of a quality to support a Tier 1 assessment.

5. The process of Ecological Risk Assessment (ERAs) were also reviewed. ERAs are used to assess every other byproduct, bycatch or TEP species interacting with the fishery, but not subject to a tiered assessment. ERA methods were developed by Commonwealth Scientific and Industrial Research Organisation (CSIRO) and AFMA to assess and monitor the risk posed by Commonwealth fisheries to the ongoing sustainability of species populations (stocks), habitats and communities. ERAs underpin AFMAs Ecological Risk Management Framework (ERMF) and assist AFMA in meeting its related legislative, corporate and policy objectives, including to gain accreditation for its fisheries under Part 13 of the EPBC Act, and assist its fisheries to gain accreditation against other standards/processes (e.g. Marine Stewardship Council (MSC)). The ERA/ERM Framework has recently been reviewed and revised to improve and streamline analysis and reporting.

1.4. Evaluation of Monitoring and Assessment Scenarios

Recent costs of the various components of data collection, data analysis, assessment types and process components (including staff participation in meetings) were calculated from information supplied by AFMA and CSIRO. Individual assessment costs were estimated for each assessment "Tier" and annual 'fixed' data collection and processing costs were allocated to the assessment tiers to allow alternative assessment scenarios to be evaluated.

In order to assess potential future costs of fisheries assessments and their underlying data needs, a method was developed to classify species as "Primary", "Secondary", "Byproduct" and "Bycatch" based on the quantity and value of individual species catches compared to the entire fishery, using catch and percent gross value of production cut off values for each category. On a SESSF-wide basis this resulted in 11 Primary species, 20 Secondary species, 79 Byproduct species and 560 Bycatch species.

The options that were explored are variants of the current 4-Tier system of data collection, monitoring and assessment. In this system: the most important quota species have extensive fishery-dependent and fishery-independent data collection to support fully-integrated, quantitative (Tier 1) stock assessments of fishing mortality (*F*) and relative biomass (*B*); *F*-based (Tier 3) assessments using size or age data are applied to two quota species; remaining quota species are assessed based on (Tier 4) empirical estimates of relative biomass based on time-series fishery dependent catch per unit effort (CPUE) data; and, Ecological Risk Assessments (ERAs) are applied to the many hundreds of other byproduct and bycatch species. "Current" scenarios kept these same (2015) Tier levels for each species whereas the "Option 1" scenarios alternative assessments were manually altered for a number of species to reflect the preferred and most likely methods to be applied to each species. "AFMA" options were applied to some of the scenarios to reflect a more automated approach to aspects of data services and standardisation by AFMA.

An Excel spreadsheet was developed to enable comparison of alternative monitoring and assessment scenarios, mainly by varying assessment types used per species and assessment frequency. To establish a baseline for comparison, a 'Default' assessment scenario was specified, based on the originally intended assessment types and annual frequency of these assessments, together with default management targets and assessment methods for the various species categories reflecting the intention to:

- Manage primary (target) species to a B_{MEY} (Biomass at Maximum Economic Yield) target, as required under the Commonwealth Harvest Strategy Policy, using annual Tier 1 (integrated statistical) assessments;
- Manage secondary species, that do not contribute substantially to Gross Value of Production (GVP), to a B_{MSY} (Biomass at Maximum Sustainable Yield) target, as has already been agreed

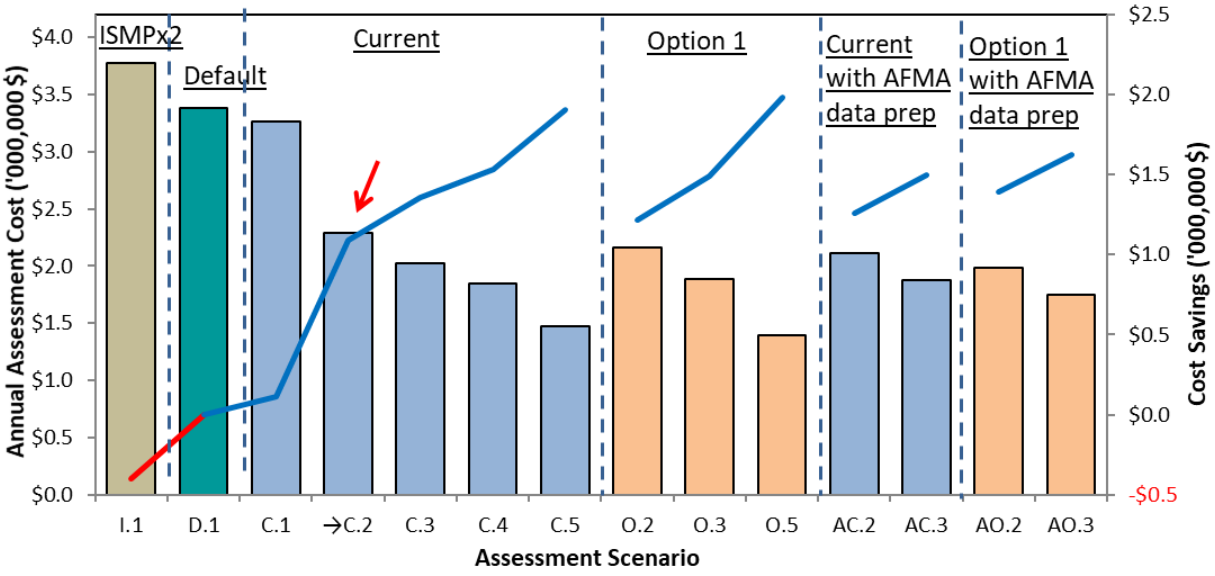
for some SESSF secondary species, using annual Tier 4 (standardised Catch Per Unit Effort (CPUE) trend) assessments. In this often highly mixed fishery it may not be possible to maintain all secondary species at a target of B_{MSY} and some flexibility may be required.

- Manage Byproduct species to ensure that they remain above the Limit in 9 years out of 10 using Tier 5 (catch-based) assessments;
- Manage the impact on Bycatch species to ensure that they remain at low risk (with an implied 9 years out of 10 probability of being above the Limit) using ERAs conducted every five years.

The alternative monitoring and assessment scenarios explored are summarised in the table and figure below, showing how each scenario was altered in terms of assessment types and monitoring and assessment frequency and the resultant overall annualised costs for SESSF monitoring and assessment (excluding additional management-related costs).

Brief description of scenarios. C.2 generally reflects the current assessment and monitoring situation. Shaded scenarios (O.3 and AO.3) are those considered to be optimal. (Bolded items indicate sequential changes from the original intention, or from the preceding option. Option 1 and AFMA data preparation scenarios are numbered as for the comparable Current scenarios.) Acronyms used in this table are as follows: Multi-year Total Allowable Catches (MYTACs); Integrated Scientific Monitoring Program (ISMP)

Assessment	Scenario	Description
I.1	ISMPx2	Explores costs of **doubled observer coverage**
D.1	Original Default	Annual monitoring; Annual FIS; Assessment using default species classifications & **Default Assessment Tiers**, 5-year ERAs
C.1	Current	Annual monitoring; Annual FIS; Assessment using actual Tiers as currently applied by the RAGs, 5-year ERAs (original intention)
→C.2	**Current**	**Annual monitoring; 2-year FIS; Current RAG Assessment Tiers, 3-year MYTACs, 5-year ERAs** (closest to current)
C.3	Current	Annual monitoring; 2-year FIS; **3-year Data Methods, Ageing & CPUE Standardisation**; Current RAG Assessment Tiers, 3-year MYTACs, 5-year ERAs
C.4	Current	Annual monitoring; 2-year FIS; 3-year Data Methods, Ageing & CPUE Standardisation; Current RAG Assessment Tiers and **5-year MYTACs; 10-year ERAs**
C.5	Current	Annual logbook monitoring; **3-year ISMP; 3-year FIS**; 3-year Data Methods, Ageing & CPUE Standardisation; Current RAG Assessment Tiers and 5-year MYTACs; 10-year ERAs
O.2	Option 1	Annual monitoring; 2-year FIS; **Modified Assessment Tiers,** 3-year MYTACs, 5-year ERAs
O.3	Option 1	Annual monitoring; 2-year FIS; 3-year Data Methods, Ageing & CPUE Standardisation; **Modified Assessment Tiers**, 3-year MYTACs, 5-year ERAs
O.5	Option 1	Annual logbook monitoring; 3-year ISMP; 3-year FIS; 3-year Data Methods, Ageing & CPUE Standardisation; **Modified Assessment Tiers**, 5-year MYTACs; 10-year ERAs
AC.2	Current + AFMA	Annual monitoring; 2-year FIS; **Annual AFMA automated analysis and reporting**; Current RAG Assessment Tiers and 3-year MYTACs, 5-year ERAs
AC.3	Current + AFMA	Annual monitoring; 2-year FIS; **Annual AFMA automated analysis and reporting**;3-year Data Methods, Ageing & CPUE Standardisation; Current RAG Assessment Tiers, 3-year MYTACs
AO.2	Option 1 + AFMA	Annual monitoring; 2-year FIS; **Annual AFMA automated analysis and reporting;** Modified Assessment Tiers, 3-year MYTACs, 5-year ERAs
AO.3	Option 1 + AFMA	Annual monitoring; 2-year FIS; **Annual AFMA automated analysis and reporting;** 3-year Data Methods, Ageing & CPUE Standardisation; Modified Assessment Tiers, 3-year MYTACs, 5-year ERAs



Comparison of estimated costs (columns) and cost savings (blue lines) of alternative assessment scenarios, as described in the above table. The red arrow indicates the scenario (C.2) closest to current practice. The AC and AO scenarios are comparable with the similarly numbered C and O scenarios, but with AFMA automating some aspects of data analysis and reporting.

There is a trade-off of cost and benefit applicable to levels (tiers) of assessment. The more costly and detailed (i.e. data intensive) Tier 1 assessments enable higher catches for the same risk (to sustainability of stocks and to the ecosystem more generally) but are costly in terms of data required and assessment costs. The less data intensive, lower tiers of assessment are cheaper but, because the assessments are less certain, result in lower TACs. Industry potentially forgoes catch (with reduced TAC) and potential economic return, but with lower costs for monitoring and assessment. Much of the stakeholder response addressed such trade-offs, resulting in several scenarios of monitoring and assessment (intensity and frequency) being evaluated (see Table and Figure below). Significantly, for many stocks within the SESSF, TACs remain significantly under-caught each year. As a result of these under-caught TACs, projections of economic returns are less than potentially expected, reducing the benefits that should accrue from conducting higher information assessments and achieving higher TACs. This reduces the lost opportunity costs (in terms of forgone catch for some species) of operating with longer-term assessment periods and lower Tier levels are not realised, although there would remain some level of lost opportunity cost for key commercial species if low information (Tier 4) assessments were conducted for all species. This study identified a need to examine reasons for consistent under-catch of certain quota species.

In general, there was little support among the reference group for options that reduced data collection from current levels (e.g. scenarios C.5 and O.5), because this was felt to overly compromise the potential to conduct assessments to meet government and stakeholder expectations from the fishery. Similarly, options with extended (>5 year) periods between assessments or ERAs were considered to be too long, given the changes that could occur in the fishery over this timeframe. However, there are benefits to be obtained by optimising the type of assessment conducted (using lower information assessments for secondary species, or for those with inadequate information for statistical integrated assessments), and by automating some aspects of standard data preparation in-house by AFMA (Scenarios O.3 and AO.3).

Scenario AO.3 was therefore seen to be the potentially optimum schedule for monitoring and assessment in the SESSF and is the scenario recommended for consideration by the SESSFRAG and SEMAC. In this scenario, there is no compromise on current data collection, but major data analyses and assessments are only conducted every three years to support a regime of 3-year MYTACs for quota species and 3-year ERAs for byproduct and bycatch species. In the intervening years, a system of automated data analysis and reporting can be conducted within AFMA to monitor key indicators and ensure that no breakout rules have been triggered (either for single-species assessments or ERAs), TEP interactions are monitored and reported, and there has been no major change in fishery dynamics (spatial and temporal catch and effort). This Scenario would continue to meet all of the current legislative and policy reporting requirements while achieving a substantial reduction in costs and assessment load.

The annual cost (using estimated costs for monitoring and assessment but excluding additional management related costs) for Scenario AO.3 is about $1,757,000 representing 2.6% of GVP, but is a saving of $1,627,000 from the Default Scenario and a saving of $539,000 compared to the current monitoring and assessment level (C.2). Further savings using AO.3 may be achieved if reduced risks — resulting from low fishing effort levels and/or under-caught TACs — enable a further increase in the period between assessments, or reduction in mitigation requirements for particular fisheries.

Scenario AO.3 cannot be implemented immediately, however, because it requires modified data collection, analysis and reporting procedures to be set up and automated within AFMA. A quantitative MSE should also be conducted to ensure that any increased risks of adopting this approach are within acceptable levels, noting that an MSE has not yet been conducted to evaluate the implications for management and risk of the current scheduling monitoring and assessment under MYTACs. In the meantime, Scenario O.3 is recommended for immediate implementation while this additional work is conducted. This will require species classification, agreement on assessments to apply to each tier and monitoring of appropriate indicators and triggers to detect situations in which assessments may need to be brought forward, or deferred.

The use of emerging information collection technology, including e-logbooks and e-monitoring, offers further savings and efficiencies in data collection. However, further work is required to align data collection, storage and distribution (from electronic sources) to ensure that monitoring and assessment continues to address the needs of management (robust assessments) and Industry needs (cost savings).

Keywords: Southern and Eastern Scalefish and Shark Fishery (SESSF), Fisheries Management, Monitoring and Assessment, Fishery-Independent Survey, Economic Return, Ecological Risk Assessment, Ecosystem Based Fisheries Management, Electronic logbooks and Monitoring.

1.5. Recommendations (bold represents high priority)

2. Introduction

The SESSF was established in 2003 by the amalgamation of the South East Trawl, Great Australian Bight Trawl, Southern Shark Non-Trawl and South East non-trawl fisheries. The SESSF is a major supplier of fresh fish to the south-eastern states of Australia and has the second highest gross value of production (GVP) of any Commonwealth fishery, at around $90 million in 2012-13. The research (e.g. Fishery Independent Surveys) and monitoring (e.g. observers) budget is about $2 million per annum with up to an additional ~$1 million allocated to stock assessments and to other supporting research. These costs are largely recovered from industry, creating strong incentives to ensure that monitoring, assessment, and management are as cost-effective and efficient as possible.

The SESSF is managed under the SESSF Harvest Strategy Framework. This framework consists of a number of harvest strategies appropriate to information availability, designed to achieve a sustainable harvest with optimal economic returns from the main species in this fishery. Under these strategies, TACs are in place for 34 quota species, with catch trigger limits applied to two non-quota species. Ecological risk assessments are conducted every five years to ensure byproduct, bycatch and TEP species are not unduly impacted. Additional spatial management and gear controls are used to reduce impacts on bycatch species such as gulper sharks, seabirds, and marine mammals.

The SESSF Harvest Strategy Framework was introduced in 2005 and provided substantial input to the development of the Commonwealth Harvest Strategy Policy (HSP), which was introduced in 2007 (DAFF, 2007). At that time, the HSP reflected world best practice in evidence-based fisheries management in many respects. Since then, the HSP has provided overarching policy guidance for management of all Commonwealth fisheries towards maximum economic yield targets. The 2012 Review of Commonwealth Fisheries: Legislation, Policy and Management review (Borthwick Review), and contemporaneous reviews of the Commonwealth Fisheries Harvest Strategy Policy and Guidelines and the Commonwealth Policy on Fisheries Bycatch (Haddon *et al.,* 2013a; Penney *et al.,* 2013; Tuck *et al.,* 2013; Vieira and Pascoe, 2013; Ward *et al.;* 2013; Haddon *et al.,* 2014) found the HSP to have been effective in rebuilding stocks and ensuring sustainability, but signalled potential changes that could be made to further improve to fisheries management which will flow on to monitoring and assessment arrangements.

The outcomes of the HSP review indicate the need for revisions to elements of that policy to respond to experiences and developments since introduction of the policy, and to ensure that Australian fisheries, including the SESSF, continue to be viewed, locally and internationally, as sustainably and responsibly managed. There is a need to inform growing public expectations in this regard, and to maintain and improve access to markets that increasingly have their own sustainability expectations. This is necessary to secure the future of Australian fishery's contribution to food provision, primary production, employment and generation of revenue.

The overall purpose of this project is to review the monitoring and assessment required to meet the objectives of the management of the SESSF (including the revised HSP and Fisheries Bycatch Policy), and to identify and evaluate the most cost-effective monitoring and assessment options that meet these needs. In developing this project, there were considerable discussions with AFMA and with key industry associations involved in the SESSF — the Great Australian Bight Industry Association (GABIA), the South East Trawl Fishing Industry Association (SETFIA), Southern Shark Industry Alliance (SSIA) and the Sustainable Shark Fishermen's Association (SSFA). AFMA has several established consultation forums with key stakeholders, including: the fishing industry, eNGOs, recreational fishers and marine mammal experts. They expressed expectations for greater involvement in fisheries management initiatives, especially with respect to improved protection of marine wildlife, more efficient management and equitable stakeholder access to fisheries resources. These stakeholder fora will be included in consultation phases of this project.

In addition to the project team (AFMA, Malcolm Haddon, Sean Pascoe (CSIRO), Ian Knuckey (Fishwell Consulting) and Andrew Penney (Pisces Australis Pty Ltd)), a Reference Group was established consisting of key government (Department of Agriculture and Water Resources, Department of the Environment and Energy), Australian Fisheries Management Forum and stakeholder representatives (industry, eNGOs and recreational fishers). This Reference Group was consulted to identify key concerns and to provide feedback on options for improved monitoring and management of the SESSF, to ensure transparency and facilitate trust and stakeholder confidence in the project outcomes. This Group gave advice to the project team on project direction and priorities, and provided a forum for regular departmental and stakeholder review of project progress against objectives. AFMA also worked closely with the relevant Management Advisory Committee (MACs) and Resource Assessment Groups (RAGs) throughout this project, given their key roles in providing management and science advice to the AFMA Commission.

There is increased awareness of the need for ecosystem-based fisheries management, with increased public expectations for sustainable management of fished stocks and broader fishery-related impacts on ecosystems. However, reduced catch levels and increasing costs have stimulated industry calls for reduction in management costs, or for more effective use of the existing cost-recovered funds. Budget limitations have already led to reduced frequency of annual FISs (every two years and only in winter), and reduced Independent Scientific Monitoring Programme (ISMP) observer coverage, alternation of FIS and ISMP from year to year, use of Crew Member Observers (CMOs) to collect on-board length frequencies, assessing species at lower tier assessments instead of Tier 1 assessments, *ad-hoc* implementation of multiyear TACs combined with *ad-hoc* implementation of break-out rules, with a consequent reduction of the frequency of Tier 1 stock assessments. Whilst all of these approaches are practical responses, their combined influence on the effectiveness of the monitoring and assessment at achieving desired management objectives has not been formally tested.

Current budget constraints on AFMA have resulted in a departure from originally scheduled monitoring and assessment work, with increasing numbers of *ad-hoc* decisions about which components of work will be undertaken each year. Monitoring and assessment is becoming more reactive rather than strategic, with increased reliance on indicators and triggers to defer or precipitate assessments. There is growing concern by stakeholders that the present monitoring and assessment program may be lagging behind these changes in management. As a result of undercaught TACs for some species and recent declining net economic returns (ER) for the fishery, SETFIA and other industry associations are particularly concerned that fishing concession levies funding current arrangements will become unaffordable. Given AFMA's legislative objectives to ensure ecologically sustainable development, to maximise net economic returns and to ensure cost-effective fisheries management, AFMA initiated the current project to develop proposals for an improved and cost-effective research, monitoring and assessment program that will be responsive to requirements and emerging issues in the SESSF over the next 5 years and further into the future.

3. Objectives

1. In consultation with the project Reference Group, SESSFRAG and SEMAC, identify priorities, key concerns, perceived shortcomings and opportunities for improvement in monitoring and assessment arrangements for the SESSF fishery.
2. Review the efficiency and cost-effectiveness of current monitoring, assessment and management arrangements for the SESSF, and the extent to which they meet the requirements of fisheries policies, including implications of recommendations arising from the reviews of the Commonwealth Fisheries: Legislation, Policy and Management, Commonwealth Fisheries Harvest Strategy Policy and Guidelines and Commonwealth Policy on Fisheries Bycatch.
3. Conduct a qualitative assessment and initiate design of the suite of rationalised monitoring and assessment options currently being trialled against reference points implied under the revised fishery policies for target, byproduct, bycatch and TEP species groups.
4. Review recent relevant regional and international fishery developments to identify future options for improvement in the efficiency and cost-effectiveness of monitoring, assessment and management arrangements for the SESSF.
5. Provide a report using the results of the reviews to support recommendations for revised, implementable and cost-effective monitoring, assessment and management arrangements for the SESSF. These recommendations will seek to optimise the outcomes for the fishery in terms of monitoring and assessment efficiency, while meeting the objectives of the Fisheries Management Act and government policy. The report may recommend further quantitative 'next step' analyses as part of the implementation process.

4. Methods

4.1. Objective 1

An initial scoping phase was conducted to finalise objectives and the scope of the project. This involved consultation with the project Reference Group, SESSFRAG and SEMAC to confirm priorities, and to identify key concerns, perceived shortcomings and opportunities for improvement in monitoring and management arrangements for the SESSF fishery. Scoping consultations were held in the form of a focussed workshop followed by consideration of the workshop outcomes by the project team.

4.2. Objective 2

Following the priorities established during the scoping phase under Objective 1, the project team conducted reviews of the efficiency and cost-effectiveness of current monitoring, assessment and management arrangements for the SESSF, and the extent to which they meet the requirements of current fisheries policies. Some aspects of these reviews involved contributions by selected experts. The reviews evaluated the potential implications of recommendations arising from the recent reviews of the Commonwealth Fisheries: Legislation, Policy and Management (the Borthwick review), Commonwealth Fisheries Harvest Strategy Policy and Guidelines (DAFF, 2013a) and Commonwealth Policy on Fisheries Bycatch (DAFF, 2013b).

4.3. Objective 3 and 4

Responding to the results of the review of effectiveness and shortcomings of existing arrangements under Objective 2, the project team identified and evaluated alternative options for improvement in the efficiency and cost-effectiveness of monitoring and assessment arrangements for the SESSF within a risk-catch-cost framework. This included a review of regional and international developments in fisheries monitoring, assessment, and management approaches of potential relevance to the SESSF over the past decade. Existing monitoring and data collection systems were described and evaluated. Areas of redundancy or overlap were identified and the potential of these programs to collect additional information cost-effectively was assessed. Future data needs for the fishery were considered interactively with the development of proposals for alternative approaches. Existing assessment methods used for various species groups in the SESSF were also described and their assumptions and data requirements summarised.

4.3.1. Qualitative evaluation

Based on the review of regional and international developments, and recent developments within the SESSF itself, alternative assessment options were identified, together with their data requirements, potential benefits and disadvantages in terms of efficiency or cost-effectiveness. These options explored both alternative assessment methods (tiers) and scheduling. Following the identification of potential alternative approaches for cost-effective, integrated monitoring, assessment and management of the SESSF, a second formal consultation with the Reference Group, SESSFRAG and SEMAC was held to present the results of the above reviews and provide the rationale for the proposed alternative approaches. Where trade-offs exist between the costs and benefits of alternative approaches, stakeholder views on preferred positions against these trade-offs were sought. The overall purpose of the second workshop was to ensure that stakeholders were fully informed of the details, costs and benefits of all recommendations, and to seek stakeholder consensus and support for a preferred suite of alternative monitoring, assessment and management arrangements.

The recommendations for revised approaches to the monitoring and assessment of the SESSF include proposals for tiered approaches for assessment of target, secondary and minor by-product species (Tier 1 – Tier 5 assessments and ERAs), together with multi-year scheduling of assessments and other research or data analysis activities. The effectiveness of multi-year approaches in meeting the requirements of the Harvest Strategy Policy or SESSF Framework has not been tested formally using management strategy evaluation. This could not be done within the limited project budget and should be undertaken. Instead, the project team and experts undertook a qualitative evaluation of the likely effectiveness of the range of revised monitoring and assessment approaches, to provide advice on which of the proposed options are likely to offer best performance against the identified policy and stakeholder objectives. This evaluation provides some guidance on best performing options and potential risk-catch-cost trade-offs of alternative approaches. This assessment phase resulted in recommendations for additional quantitative work to formally evaluate the effectiveness of proposed monitoring, assessment and management changes in managing risk against the objectives of the HSP, but which could not be conducted within this project's budget and timeframe. This additional work could result in a proposal for a Phase 2 of the project, or could form the basis for a program of smaller quantitative management strategy evaluations conducted as part of the ongoing activities of the SESSF RAG, as part of implementation of the recommended improvements.

4.3.2. Vessel-level economic analysis methods

Vessel level economic analysis was conducted based on Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) economic survey data presented in Skirtun and Green (2015), for the 2012-13 financial year (Table 1). Individual vessel data were not available to the project, but a typical range of values across existing vessels was derived from the average values and their relative standard errors (RSE).[1]

A sample of 1000 vessels in each sector was generated from the data based around the mean and RSE. While information on covariance between the values was not available, there is prior evidence to indicate that variable costs and, in some cases fixed costs, are proportional to the level of fishing activity (Zhou *et al.,* 2012a). When developing the baseline and subsequent vessel-level values, the assumption was made that crew payments were directly proportional to revenue (as is common in the fishery), but also that freight and packaging costs (which are generally related to volume of catch) and fuel costs (generally related to effort) were also proportional to revenue. That is, for any given vessel, more revenue was assumed to require more catch and more fishing effort. Variation in revenue was simulated by comparing the relative standard errors of the variable cost items and the revenue. If the variable cost RSE was larger than the revenue RSE, then additional variation based on the difference between the two was also added. If the cost item RSE was less than the revenue RSE, then the effects of the variation in revenue were assumed to be the only variation in cost.

[1] Relative standard error (RSE) is the standard error expressed as a percentage of the mean. The relative standard error is a measure of confidence in the mean estimate based on the level of variance in the data.

Table 1. ABARES SESSF economic survey data, 2012-13.

	Commonwealth Trawl Sector		Gillnet, Hook and Trap Sector	
Item	Mean	RSE	Mean	RSE
Revenue				
• Fishing income	976725	13%	346492	16%
• Non-fishing income	78461	34%	37620	21%
Variable Costs				
• Crew	306458	9%	148259	10%
• Freight	129852	18%	13117	47%
• Fuel	173987	20%	49339	18%
• Packaging	20803	57%	471	59%
Fixed costs				
• Fixed cash costs	138285	20%	79561	16%
• Owner operator allowance	83154	13%	54453	14%
• Opportunity cost of capital	14947	20%	12974	15%
• Depreciation	20282	19%	16934	17%
• Management costs	58960	0	35176	0
Number of boats	50		72	

Source: Derived from Skirtun and Green (2015)

The effects of different assessment scenarios were evaluated by comparing the revenue given the current catch with the revenue that might occur at different TAC levels that might result from discounts applied under different assessment tiers (assuming that TACs are caught). Individual vessel revenues and associated variable costs were scaled up by the proportional change in TAC. Fixed costs were held constant in all simulations, although the change in management costs was included (generally a decrease in costs). Other non-fishing income was also included but held constant.

4.4. Objective 5

The project team and co-authors prepared this report, including results of the reviews and recommendations for viable and cost effective alternative approaches for monitoring, assessment and management of the SESSF. The recommendations in this report seek to optimise the outcomes for the fishery in terms of monitoring and assessment efficiency, while still meeting the objectives of the Fisheries Management Act 1991, the 2005 Ministerial Directive to AFMA and the HSP. The report recommends further quantitative ‘next step’ analyses as part of the implementation process. This draft final report will be reviewed by the Reference Group, SESSFRAG and SEMAC before producing a final report.

5. Results and Discussion - Objective 1

5.1. Characterisation of the Southern and Eastern Scalefish and Shark Fishery

The SESSF is a complex multi-sector, multi-species and multi-gear fishery which encompasses almost half of the Australian Fishing Zone — from Fraser Island, Queensland to Cape Leeuwin in Western Australia, and from shallow coastal waters to depths of over 1000 m (Figure 1). It is Australia's largest fishery in terms of volume produced, supplying much of the fresh fish to our domestic markets. GVP in 2015–16 was $73.0 million (Figure 2) and total landings during 2016–17 were 9,829 t (Patterson *et al.*, 2017).

The SESSF was formed during 2003 from the amalgamation of the Commonwealth South East Trawl, Great Australian Bight, Southern Shark and South East Non-trawl fisheries. This brought control of the fisheries under the common management objectives of the SESSF Management plan 2003. Differences between those fisheries are still recognised as sectors of the SESSF that are now called the Commonwealth Trawl Sector (CTS), the East Coast Deepwater Trawl Sector (ECDTS), the Great Australian Bight Trawl Sector (GABTS), and the Gillnet, Hook and Trap Sector (GHaTS). The latter can also be split into Scalefish Hook Sector (ScHS), the Shark Gillnet and Shark Hook Sectors (SGSHS), and the Trap Sector.

Management of the fishery is primarily through output controls consisting of TACs managed under an Individual Transferable Quota (ITQ) system. TACs were first introduced in 1988 for Eastern Gemfish (*Rexea solandri*) to prevent overfishing and rebuild the stock. TACs for other species have since been implemented, and there are currently TACs for 34 fish stocks / species baskets (referred to as quota species). Other output controls in the fishery include prohibition on targeted fishing for overfished species (e.g. currently gulper sharks and school shark), protected species (e.g. TEP species listed under the Environment Protection and Biodiversity Conservation Act 1999 [EPBC Act]), and trip, bycatch and size limits for some species. There are also a range of input controls including limited entry, a network of spatial closures and gear restrictions.

A variety of methods are used to monitor the SESSF. Fishers record details of their fishing operations and catches in logbooks, and accurate weights of catch for each trip in catch disposal records. The observer program records estimates of retained and discarded catch and interactions with TEP species. Observers also collect biological data including length frequency measurements and otoliths and shark vertebrae to estimate the age of individuals in catch samples. Separate fishery independent trawl surveys in the areas of the GATBS and CTS provide time-series of species composition and relative biomass estimates for a range of quota and non-quota species.

Regular stock assessments are undertaken by AFMA Resource Assessments Groups (RAGs) for 37 species in the SESSF (Tuck, 2014a, b). The RAGs apply the tiered harvest strategy framework to determine stock status against reference points and provide advice to the SEMAC on recommended biological catches (RBCs) and on the impact of fishing on the marine environment. In turn, AFMA Management and SEMAC provide advice to the AFMA Commission on TACs and other management measures. Stocks are annually assessed by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) in terms of "Overfishing", relating to excessive fishing mortality, and "Overfished", relating to depleted biomass. A total of 31 SESSF stocks were assessed as being "not subject to overfishing" in 2016, while 6 stocks were assessed as "uncertain if subject to overfishing" (Patterson *et al.*, 2017; Figure 3). For the same year, 27 stocks were assessed as "not overfished", 7 were "overfished" and 3 were "uncertain if overfished" (Figure 4).

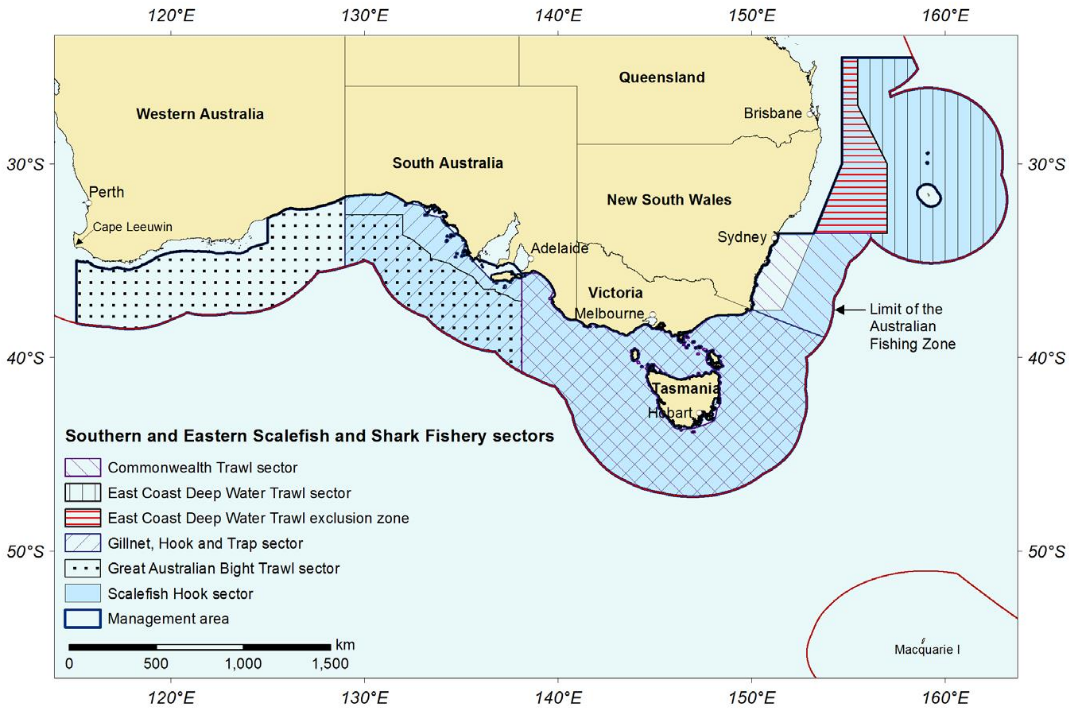


Figure 1. Management area of the SESSF and each sector (reproduced from Patterson *et al.*, 2017).

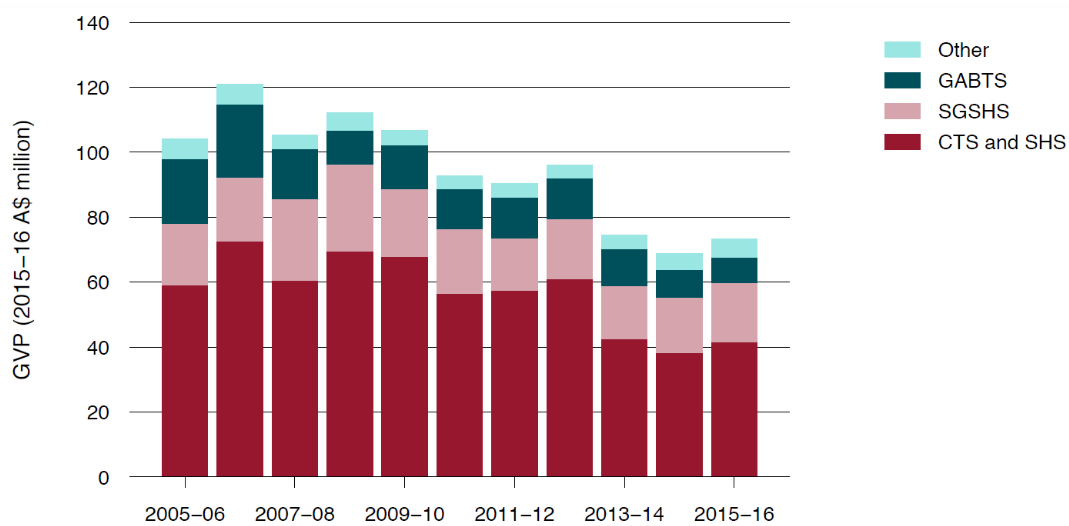


Figure 2. Real GVP in the SESSF by sector from 2005–06 to 2015–16 (reproduced from Patterson *et al.*, 2017).

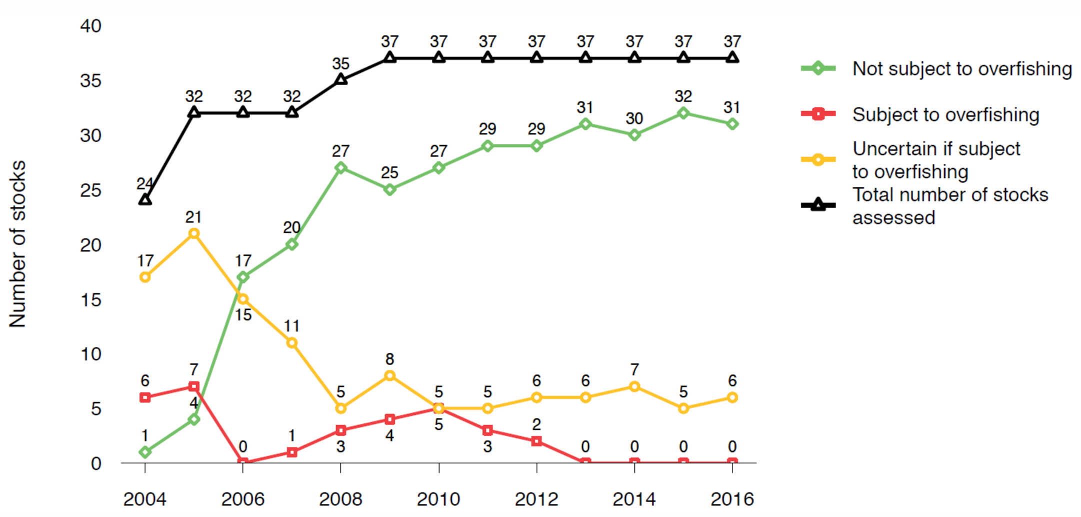


Figure 3. Fishing mortality status for all stocks in the SESSF from 2004 to 2016 (reproduced from Patterson *et al.*, 2017). Note the number of stocks assessed each year does not remain constant through time.

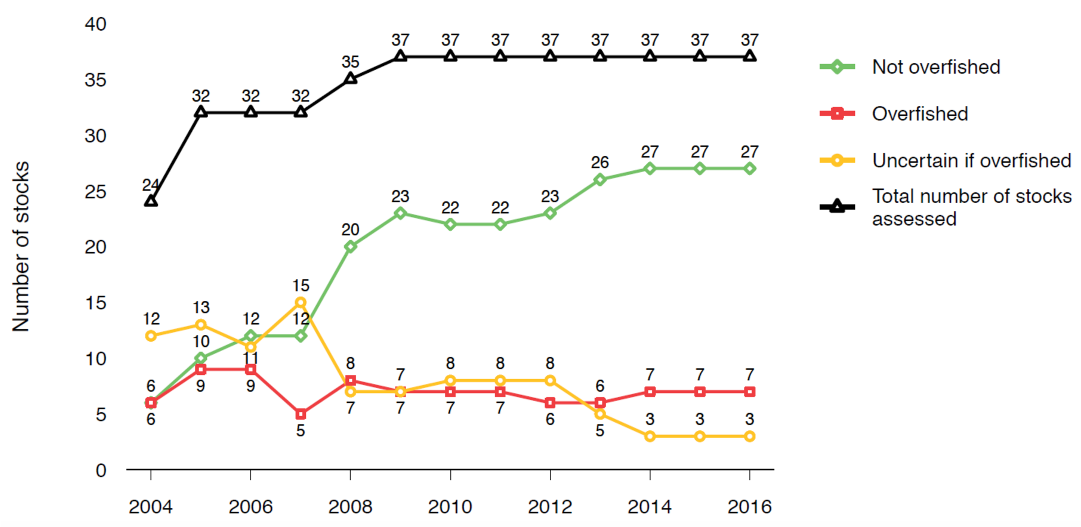


Figure 4. Biomass status for all stocks in the SESSF from 2004 to 2016 (reproduced from Patterson *et al.*, 2017).

5.1.1. The Commonwealth Trawl Sector

The area of the CTS ranges from Barranjoey Point (north of Sydney) south around the Victorian and Tasmanian coastlines to Cape Jervis in South Australia (Figure 1). It comprises two sectors, the South East Trawl Fishery (SETF) and the Victorian Inshore Trawl Fishery (CVIT). The main fishing methods used by the CTS are otter trawl and Danish seine. Midwater trawling and pair trawling are also permitted. There are 22 CVIT permits. For the Commonwealth fishery during 2016–17 there were 34 active otter trawl and 16 active Danish seine vessels.

Catches in the CTS peaked in 1990 at more than 60,000 t with large catches of Orange Roughy (*Hoplostethus atlanticus*) and Blue Grenadier (*Macroronus novaezelandiae*), and fluctuated around 20,000 t –30,000 t from 1993–2004 (Figure 5). Catches fell below 15,000 t in 2006 after the structural adjustment associated with the introduction of the Commonwealth HSP significantly reduced effort in the fishery (by about 50%). During the 2016–17 fishing year, the CTS landed a total of 7,634 t of quota managed species, and the GVP of scalefish catches in the CTS was $36.80 million in 2015–16 (Figure 6). Although more than 100 different species are landed, the main species caught are Blue Grenadier, Tiger Flathead (*Neoplatycephalus richardsoni*), Pink Ling (*Genypterus blacodes*) and Silver Warehou (*Seriolella punctata*) which together comprise about three-quarters of the catch.

Some 500 additional byproduct or bycatch species are incidentally caught, and overall discard rates for the CTS are about 40–50% (Figure 7), comprising mostly non-quota species (85–95%) such as Barracouta (*Thyrsites atun*), New Zealand Dory (*Cyttus novaezealandiae*), Whiptails (*Macrouridae and Bathygadidae*), Cocky Gurnard (*Lepidotrigla modesta*), Frostfish (*Lepidopus caudatus*), Skates and Rays (*Rajidae* and *Dasyatidae*), Blacktip Cucumberfish (*Paraulopus nigripinnis*), Dogfish (*Squalidae*), Swellsharks and Draughtboard Sharks (*Cephaloscyllium spp*), and Stingarees (*Urolophidae*) (Tuck *et al.,* 2013). Main quota species discarded include Silver Warehou, small Blue Grenadier, small Tiger Flathead and Reef Ocean Perch (*Helicolenus percoides* — previously Inshore Ocean Perch). Management changes implemented to reduce bycatch include increased mesh size and use of bycatch reduction devices.

Interactions with TEP species are required to be reported by fishers in their logbooks, and are also reported by fisheries observers. Interactions are generally rare and highly variable. During the 2016–17 financial year, AFMA (2017a) shows that CTS operators reported interactions[2] with 135 seals (mostly Australian Fur Seals, *Arctocephalus pusillus doriferus*), 9 dolphins, 17 seabirds (mostly albatross), 1 Mako Sharks (*Isurus* spp) and 1 Great White Shark (*Carcharodon carcharias*) summarised from reports by. A range of measures has been implemented to reduce TEP interactions including:

- seabird management plans (SMPs) that include mandatory use of seabird mitigation devices;
- codes of conduct for fur seal catch reduction;
- education programs; and
- use of seal excluding devices by midwater trawls.

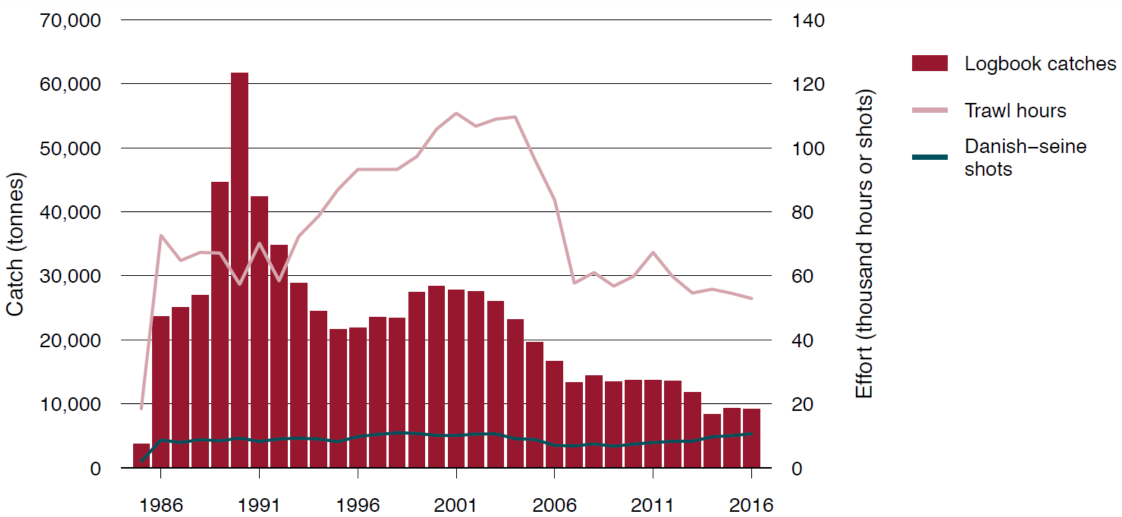
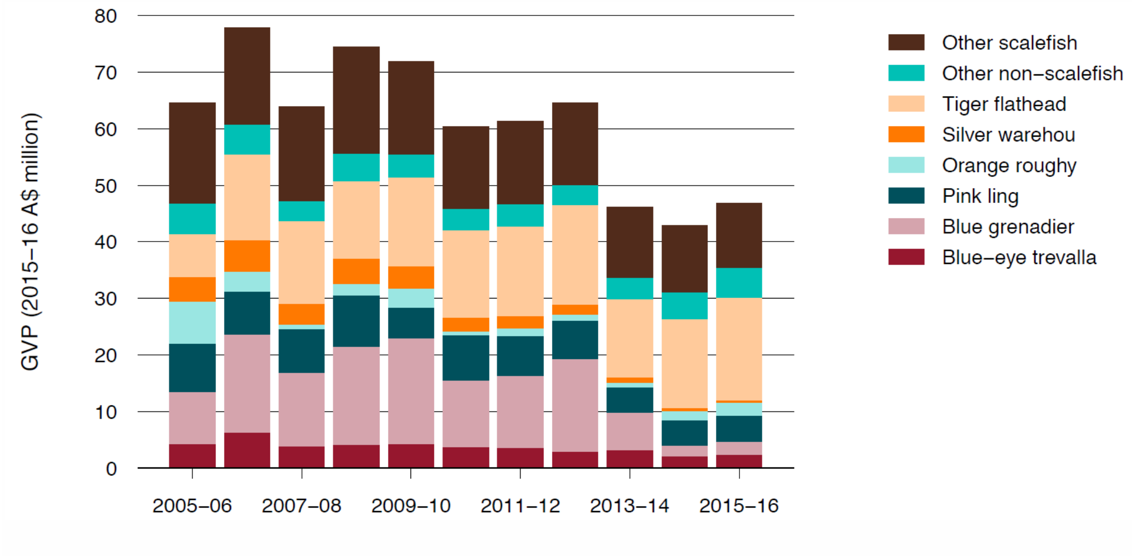


Figure 5. Total catch and fishing effort for the CTS from 1985 to 2016 (reproduced from Patterson *et al.*, 2017).

2 The MOU for The Reporting of Fisheries Interactions with Protected Species Under the *EPBC* Act (http://www.afma.gov.au/wp-content/uploads/2010/06/mou.pdf) defines an interaction as "any physical contact an individual has with a protected species. This includes all catching (hooked, netted, entangled) and collisions with an individual of these species."



Note: **GVP** Gross value of production.

Figure 6. Real GVP by key species for the CTS and ScHS from 2005–06 to 2015–16 (reproduced from Patterson *et al.*, 2017).

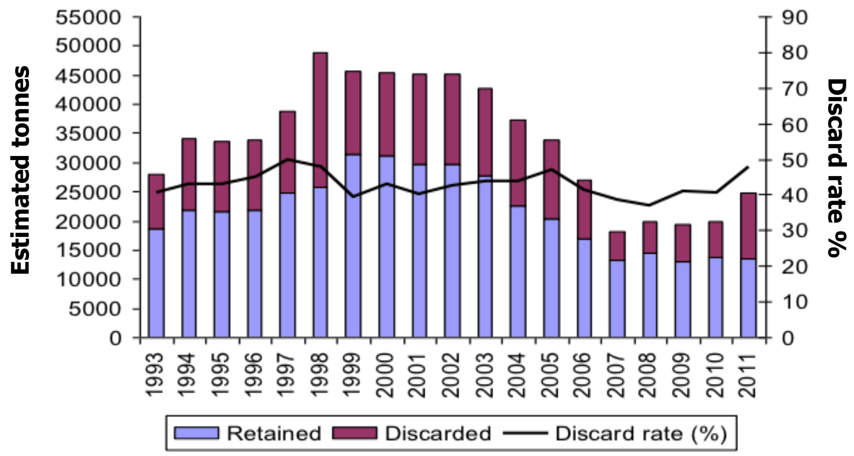


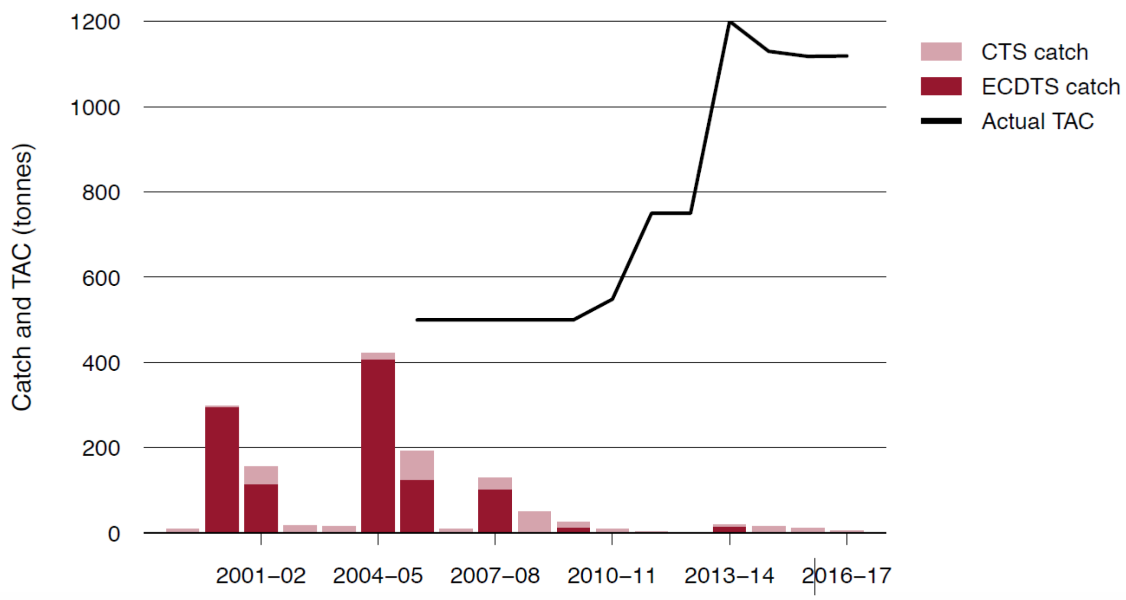
Figure 7. Estimated retained and discarded catch (t) and estimated discard rate (%) for the CTS for quota and non-quota species combined (reproduced from Tuck *et al.*, 2013). Note there were no observations in NSW before 1998 in the AFMA database.

5.1.2. The East Coast Deepwater Trawl Sector

The area of the ECDTS extends northwards from Sydney up to Fraser Island, including waters surrounding Lord Howe Island out to the limits of the Australian Fishing Zone (Figure 1). Fishing methods used are otter trawling and midwater trawling. While there are 10 fishing permits for the ECDTS, no vessels were active in the sector during 2016–17 (Patterson *et al.*, 2017).

The main species targeted in the ECDTS is Alfonsino (*Beryx splendens*). Catches have been as high as 400 t during 2004–05, and was 15 t in 2012–13 and 2013–14 respectively (Figure 8). No catch was recorded by the fishery in 2016–2017.

No interactions with TEP species were reported in the ECDTS for 2016 (Patterson *et al.*, 2017).



Notes: **CTS** Commonwealth Trawl Sector. **TAC** Total allowable catch.

Figure 8. Catch and TAC for Alfonsino in the ECDTS and CTS from 2000–01 to 2016–17 (reproduced from Patterson *et al.*, 2017).

5.1.3. The Great Australian Bight Trawl Sector

The GABTS ranges from Cape Leeuwin, Western Australia, to Cape Jervis near Kangaroo Island, South Australia (Figure 1). There are 10 fishing permits and, during 2016–17, there were 4 active otter trawl vessels and 1 active Danish seine vessel, which fished 12,480 trawl hours and 442 seine shots respectively. Most fishing occurs on the continental shelf targeting Deepwater Flathead (*Platycephalus conatus)* and Bight Redfish (*Centroberyx gerrardi*), but some fishing occurs for slope species such as Blue Grenadier (*Macroronus novaezelandiae*), Western Gemfish (*Rexea solandri*) and Pink Ling, as well as for Orange Roughy (*Hoplostethus atlanticus*).

GABTS catches reached a peak of more than 4,000 t during 2003–04, but catches steadily declined and 1,138 t was landed in 2016–17 (Figure 9 and Figure 10). In 2015–16 the value of the catch was about $7.69 million (Figure 11). The annual catch of Deepwater Flathead peaked at nearly 2,500 t in 2003, and 636 t of Deepwater Flathead was landed in the 2016–17 financial year. Bight Redfish catches peaked at more than 1,000 t in 2006–07 and catches have declined to 274 t in 2016–17. Main byproduct species are Ocean Jacket (*Nelusetta ayraud*), Angel Shark (*Squatina* spp.), Yellow-spotted Boarfish (*Paristiopterus gallipavo*), Western Gemfish and Jackass Morwong (*Nemadactylus macropterus*).

Estimates of discard rates for the GABTS from the early 2000s ranged from 30–60% for quota and non-quota species combined (Figure 12), with more than 99% of discards being non-quota species (Tuck *et al.*, 2013). Other main discard species include Latchet (*Pterygotrigla polyommata*), Ocean Jacket, skates and rays.

Observers have recorded interactions with seabirds (Flesh Footed Shearwaters, Shy Albatross) and pipefish by the GABTS (Tuck *et al.*, 2013). Interactions with 1 seabird and 1 Syngnathid were recorded by operators during the 2016–17 financial year. Measures that have been implemented to reduce TEP interactions include SMPs and a Boat Operating Procedures Manual that includes a section on TEP interactions.

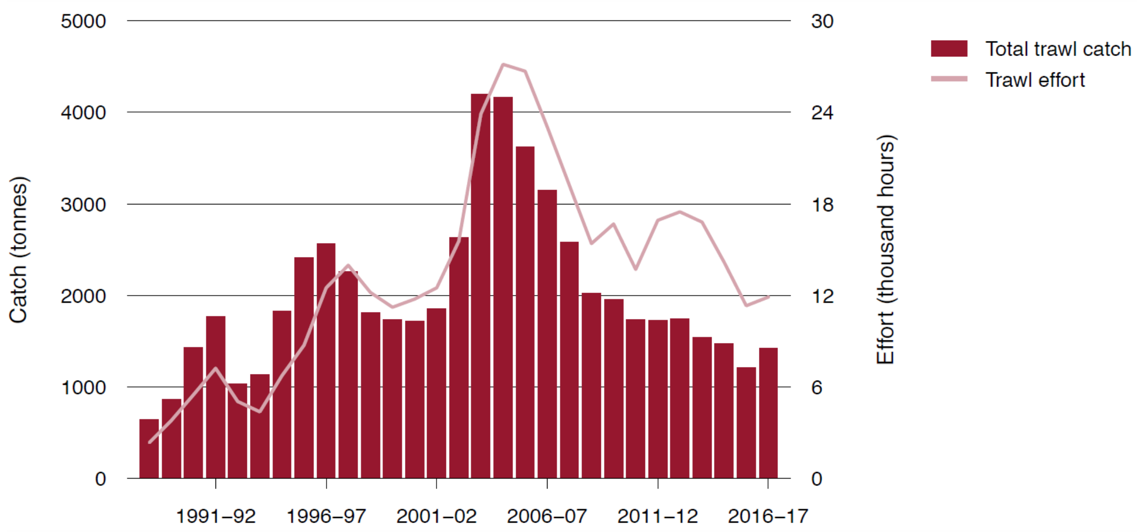


Figure 9. Catch and effort on the GABTS shelf from 1988–89 to 2016–17 (reproduced from Patterson *et al.*, 2017).

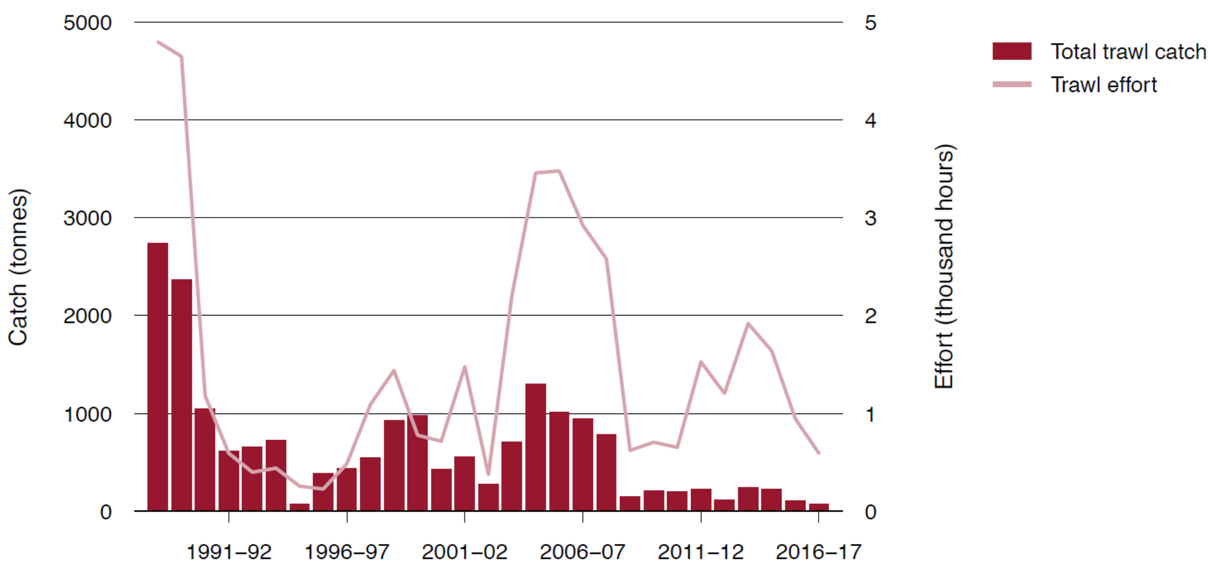


Figure 10. Catch and effort on the GABTS slope from 1988–89 to 2016–17 (reproduced from Patterson *et al.*, 2017).

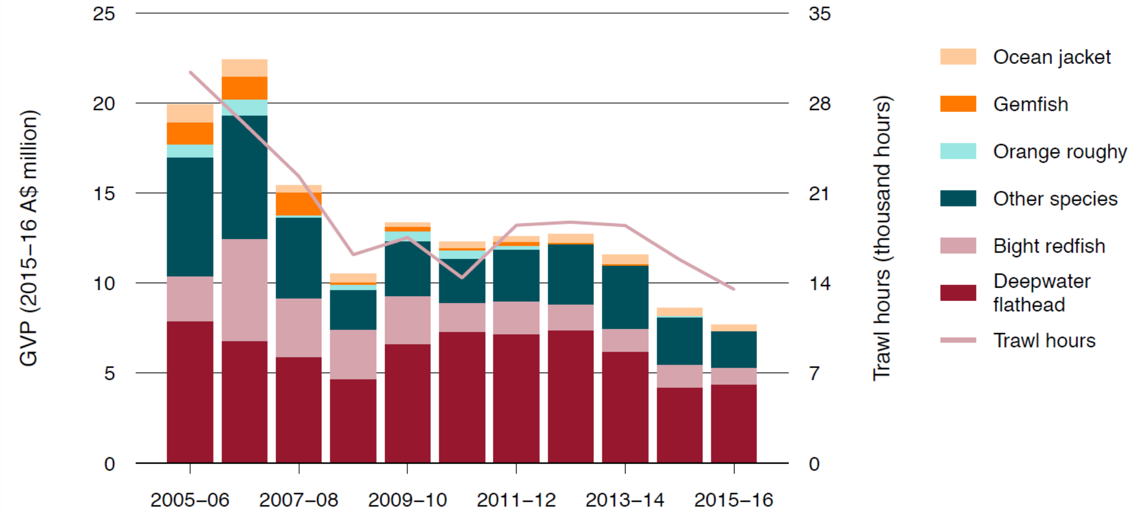


Figure 11. GVP in the GABTS in real terms by species and trawl hours from 2005–06 to 2015–16 (reproduced from Patterson *et al.*, 2017). Note: GVP is Gross value of production. Trawl hours do not include Danish seine effort. There was one active Danish-seine vessel from 2012–13 to 2016–17.

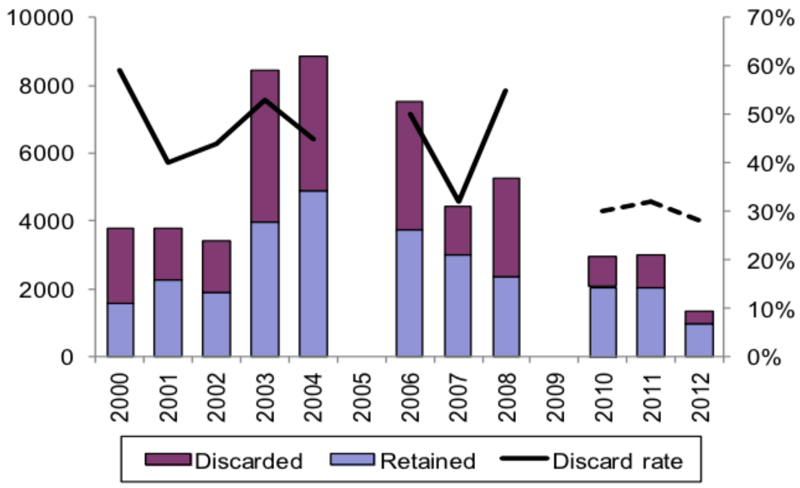


Figure 12. Estimated retained and discarded catch (t) and estimated discard rate (%) for the GABTS for quota and non-quota species combined (reproduced from Tuck *et al.*, 2013). The solid line represents discard rates estimated from the ISMP data and the dashed line represents discard rates obtained from industry logbooks. Note that 2012 represents a partial year of data.

5.1.4. The Gillnet, Hook and Trap Sector - Scalefish Hook

The ScHS ranges from Fraser Island, Queensland, around south-east Australia to the Western Australian–South Australian border (Figure 1). There are 37 ScHS Statutory Fishing Rights (SFRs), and during 2016–17, there were 17 active vessels which set a total of 3.192 million hooks. Fishing methods permitted include dropline and demersal longline, including automatic baiting equipment. This sector targets mainly Pink Ling (*Genypterus blacodes*) and Blue-eye Trevalla (*Hyperoglyphe antarctica*) on the continental slope. The use of automatic baiting equipment is prohibited inside the automatic longline shallow water closure that approximately follows the 183 m depth contour.

Total landings by the ScHS peaked in 2004 at about 1,500 t, and effort peaked the following year when more than 10,000,000 hooks were set (Figure 13). Both catch and the number of hooks set have since declined and during 2016–17, the sector landed just over 600 t (Patterson *et al.*, 2017). Catches of Blue-eye Trevalla and Pink Ling by the ScHS in 2016–17 were 388 t and 305 t respectively (Patterson *et al.*, 2017).

Discard rates for the ScHS are generally low. Recent discard rates have not been determined. However 2006 discard rates for quota and non-quota species were <1% and <6% respectively (Koopman *et al.*, 2007). The only quota species reported as discarded by dropline gear was Eastern Gemfish (*Rexea solandri*), whereas the main discarded quota species by longline gear were School Shark (*Galeorhinus galeus*) and Offshore Ocean Perch (now Bigeye Ocean Perch, *Helicolenus barathri*). Main non-quota discard species by dropline gear were White Warehou (*Seriolella caerulea*), and by longline gear were Spikey Dogfish (*Squalus megalops*), Draughtboard Shark (*Cephaloscyllium laticeps*) and Southern Dogfish (*Centrophorus zeehaani*).

Longline and drop line fishers reported interactions with a variety of TEP species during the 2016–2017 financial year, comprising mostly Seabirds, Shortfin Mako (*Isurus oxyrinchus* and Porbeagle Shark (*Lamna nasus*). Although such reports are not separated by gear (and so include SGSHS interactions – see next section), Tuck *et al.* (2013) reported that the main observer-recorded TEP interactions during 2010 were with Harrisson's Dogfish (*Centrophorus harrissoni*), Flesh Footed Shearwater (*Puffinus carneipes*) and Australian Sea Lion (*Neophoca cinerea*). A range of management measures have been implemented to reduce TEP interactions — particularly for automatic longlines — including area closures, use of tori lines, a ban on discharging offal while setting and hauling, minimum sink rates and thawing of baits.

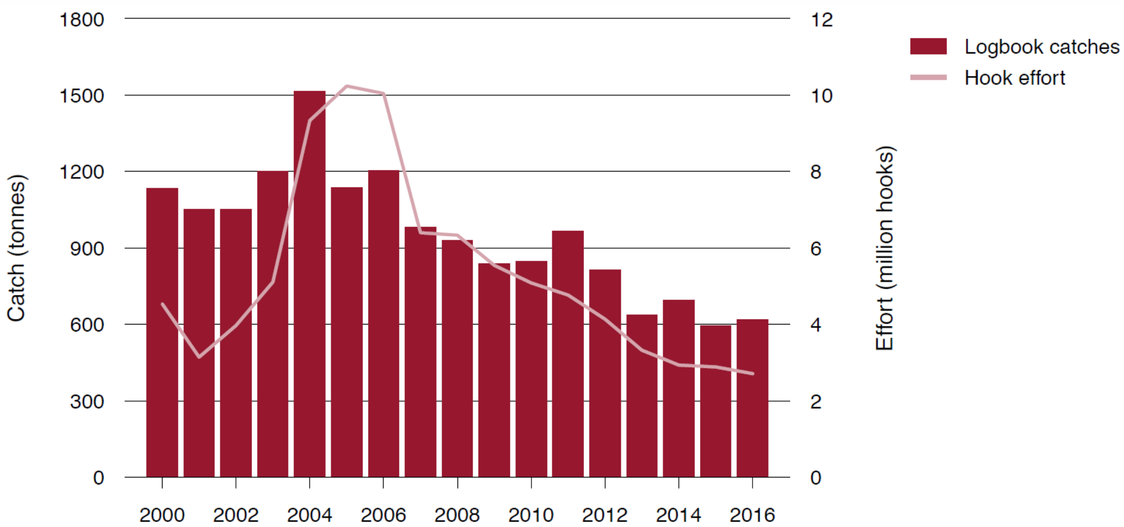


Figure 13. Total catch and fishing effort for the ScHS from 2000 to 2016 (reproduced from Patterson *et al.*, 2017).

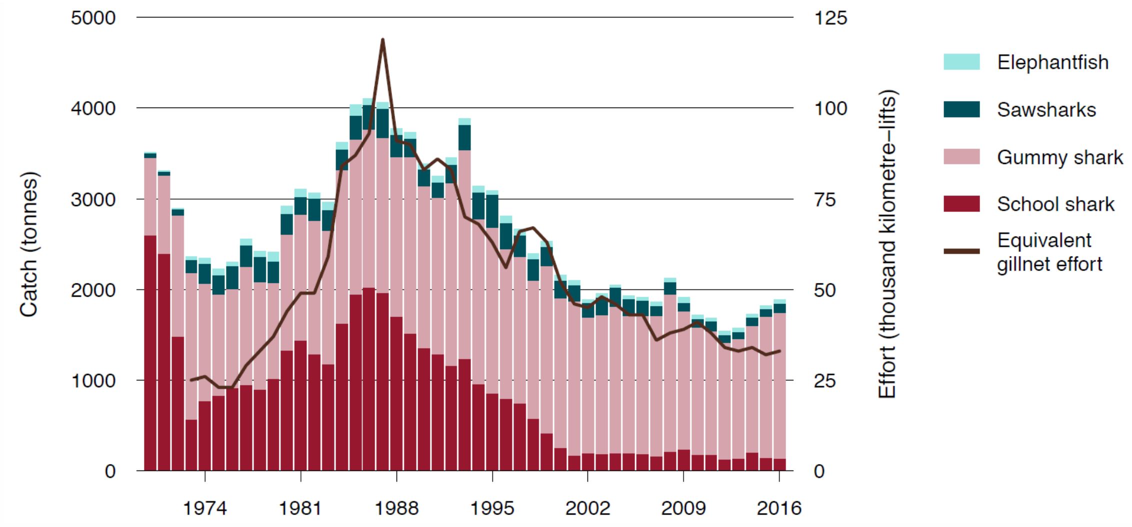
5.1.5. The Gillnet, Hook and Trap Sector – Shark Gillnet and Shark Hook

The area of the SGSHS extends south from the New South Wales–Victoria border, around south-east Australia to the Western Australia–South Australia border (Figure 1). Most fishing occurs in coastal waters including Bass Strait, and the fishery is restricted to depths shallower than 183 m by the Shark Hook and Gillnet Deepwater Closure. There are currently 61 gillnet and 13 hook SFRs, and during 2016–17 there were 36 active gillnet vessels and 26 active hook vessels (Patterson *et al.*, 2017). Fishing methods used by the SGSHS include demersal gillnet, demersal longline, dropline, mechanised handline and auto-longline. The main species caught are Gummy Shark (*Mustelus antarcticus*), Elephant Fish (*Callorhinchus milii*), Sawsharks (*Pristiophoridae*) and School Shark (*Galeorhinus galeus*).

Catch of the main species taken by the SGSHS during 2013–14 was 1,832 t (Figure 14), comprising mostly Gummy Shark (1,526 t), School Shark (149 t) and 112 (70 t) (Patterson *et al.*, 2017). Gummy Shark catches were relatively stable at about 1,700 t per year through the mid-1980s to the late 1990s when catches dropped to about 1,500 t per year, but have steadily increased since 2012. GVP of the SGSHS during 2015–16 was $17.21 million, of which $15.46 million came from catches of Gummy Shark (Figure 15).

Discarding of the main species caught by the SGSHS is low (~3%), although a fishery-independent survey estimated overall discard rate for gillnets as 32–36% (Braccini *et al.*, 2009, Tuck *et al.*, 2013). Most frequently discarded species were Draughtboard Shark, Port Jackson Shark (*Heterodontus portusjacksoni*) and Spikey Dogfish.

Interactions reported by gillnet fishers in the SGSHS during the 2016–17 included Shortfin Mako, Dolphins, Australian Fur Seal, New Zealand Fur Seals (*Arctocephalus forsteri*) and other Seals, Great White Sharks, Porbeagle Shark (*Lamna nasus*), Grey Nurse Sharks (*Carcharias taurus*) and Petrels, Prions and Shearwaters. Estimates of high levels of interactions with Australian Sea Lions[3] and observations of interactions with Common Dolphins[4] off South Australia in recent years have resulted in large spatial closures and increased observer coverage, as well as a trial of the use of automatic longlines and an increase in the use of bottom-line fishing to target Gummy Shark.

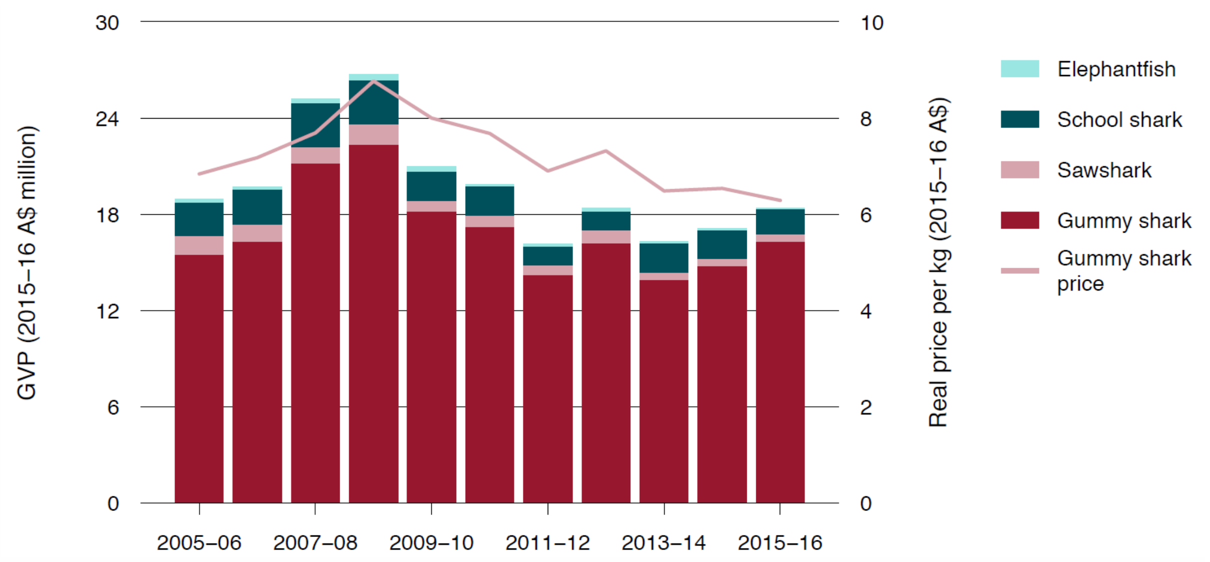


Note: 'Equivalent gillnet effort' is an estimate of total effort after converting hook effort to the equivalent gillnet effort using the methods in Walker et al. (1994).

Figure 14. Annual landings and effort in the SGSHS from 1970 to 2016 (reproduced from Patterson *et al.*, 2017).

3 Goldsworthy *et al.,* (2010) estimated that 374 Australian sea lions were removed by the gillnet sector of the SESSF in South Australia as bycatch mortality each breeding cycle (17.5 months).

4 AFMA (2014) reported that a total of 52 dolphins were caught over 12 months between late 2010 and late September 2011.



Note: **GVP** Gross value of production.

Figure 15. Real GVP of the SGSHS and real price for Gummy Shark from 2005–06 to 2015–16 (reproduced from Patterson *et al.*, 2017).

5.2. Data collection and assessments in the SESSF

5.2.1. A new beginning

A new Commonwealth fisheries log-book was introduced into the South-East Fishery (SEF) late in 1985 and was providing mostly plausible data from 1986 onwards. The GAB fishery appears to have started recording data at about the same time. Logbooks were extended to non-trawl fisheries in late 1997 (Table 2). An important innovation with the new log-book was the requirement to report fishing events at a shot-by-shot level of detail. However, in the early years of the new log-book there appear to be instances where summary data (total catches and total effort) for week or month-long periods are included with the shot by shot data.

The primary species taken in the fishery in the late 1980s were different to those currently taken. For example, catches of Eastern Gemfish (*Rexea solandri*) — once a dominant species — have now declined to low levels. Management was relatively ineffective at maintaining sustainable catches, particularly of Eastern Gemfish and Orange Roughy, in the 1980s. Accordingly, transferable quotas were introduced into the trawl fishery in 1992. Relatively simple fishery assessments were conducted, principally by ABARES (Bureau of Rural Sciences) as the basis of allocating Total Allowable Catches (TAC). However, at first TACs did little to constrain catches or fishing mortality.

5.2.2. The earliest formal assessments

The history of early research and management of the SESSF is well described by Tilzey (1994). Early cooperation between the Commonwealth and States on SESSF research was difficult to achieve but a step in this direction was achieved with the establishment of the South Eastern Fisheries Committee in 1968 and its subcommittee the Demersal and Pelagic Fish Research Group (DPFRG) in 1973. In 1985 the new South East Trawl Management Plan was introduced which saw the establishment of the South East Trawl Management Advisory Committee (SETMAC) and a mandatory logbook system was introduced. Most of the early “assessment” work was focussed on the declining Eastern Gemfish and Orange Roughy stocks. Allen (1989) conducted a cohort analysis and population modelling to determine sustainable yield estimates for the Gemfish stock. Ultimately, with the introduction of total allowable catches for 16 SEF species in 1992, SETMAC formed the Stock Assessment Group in 1993, which was the forerunner to the South East Fishery Assessment Group (SEFAG).

SEFAG began undertaking formal stock assessments for quota species on an annual basis, with particular emphasis on Redfish and Blue Grenadier. Reports were not produced for each species in every year, but the reports that were produced summarized the most recent catches and the species-specific assessment summaries for those species that were assessed. For example, in 1998 a report detailing assessments and data up to the end of 1997 was produced (Tilzey *et al.,* 1998), and this included a listing of recent assessment summaries (Table 3). A stock assessment report was produced for Redfish 1993 and with the other species from 1994 onwards (Table 3). From these baseline assessments, SEFAG moved to a more strategic approach in 1995 concentrating on those species previously identified as being a high priority by SETMAC.

At the time, catch rate data (CPUE) were used to indicate stock status. More formal assessments were developed for some of the priority species (e.g. virtual population analyses from catch at age assessment). There was no standard target status across species. Instead, a reference year was selected and either the unstandardised catch rates recorded were used as the target for each assessed species or, if a more formal assessment was available, 40% of the estimated spawning biomass in the reference year was used as a target, this being a widely-accepted proxy for the biomass which supports the maximum sustainable yield B_{MSY}:

> "In the 1996 assessment, five species failed to satisfy AFMA's performance criteria relating to catch rates. They were blue warehou, western gemfish, jackass morwong. Mirror dory, and redfish. Based on logbook data and using only shots containing the species in question, the 1995 catch rates for these species were at their lowest since 1986. SEFAG, where appropriate, brought forward planned stock assessments for these five species. Available evidence suggested that eastern gemfish stock was still below AFMA's target of 40 per cent of 1979 spawning biomass, but improving." Tilzey (1998, p 31).

SEFAG's objective was to produce an annual stock assessment report and include in that a summary of the latest stock status for each species. However, for most species an assessment consisted only of an evaluation of unstandardised catch rates. Furthermore, there was a Scientific Monitoring Program (SMP observer program) in place that provided some information on discards and some limited information on age and length composition of the catch. This information was also considered for each species if data were available. For those species for which more comprehensive data were available, including Orange Roughy, Eastern Gemfish, and Blue Grenadier, fisheries models were developed. The assessments for Arange Roughy and Blue Grenadier also included fishery independent data in the form of acoustic or egg production surveys.

> "The main aim of the SEF Strategic Research Plan, 1995 – 2000 is to collect sufficient data to enable more sophisticated modelling of most of the remaining quota species." Tilzey (1998).

In 1997 four new assessment groups were established with the aim of improving the assessments for Blue Warehou, Blue Grenadier, Orange Roughy, and redfish. All other species received only occasional evaluation but no sustained research was undertaken. In 1998, an ITQ system was introduced for Blue-eye Trevalla and Pink Ling. Accordingly, the establishment of assessment groups for those species was a high priority.

Table 2. Logbook coverage of the various fisheries included in the SESSF. The trawl and Danish seine fisheries were first provided with detailed log-books and the non-trawl were included from late in 1997. GHT = Gillnet, Hook and Trap, SEN = South-East Non-trawl, SSF = Southern Shark Fishery, SSG = Southern Shark Gillnet, SSH = Southern Shark Hook, SET = South-East Trawl, GAB = Great Australian Bight. Note that the fishery names shown in this table are historical. Current names are CTS (SET), GHaHT (GHT, SEN, SSF, SSG, SSH) and GABTS (GAB).

Year	GHT	SEN	SSF	SSG	SSH	SET	GAB
1985						X	
1986						X	X
1987						X	X
1988						X	X
…	…	…	…	…	…	…	…
1994						X	X
1995						X	X
1996						X	X
1997		X		X		X	X
1998		X		X	X	X	X
1999		X	X	X	X	X	X
2000		X	X			X	X
2001		X	X			X	X
2002	X	X	X			X	X
2003	X					X	X
2004	X					X	X
…	…	…	…	…	…	…	…
2014	X					X	X
2015	X					X	X

Table 3. A listing of species within the south east trawl fishery with the years in which stock assessments were produced in the mid to late 1990s.

Species	Scientific Name	Stock assessment report produced				
Blue-Eye Trevalla	*Hyperoglyphe antarctica*		1994	1995		1997
Blue Grenadier	*Macroronus novaezelandiae*		1994	1995		1997
Blue Warehou	*Seriolella brama*		1994	1995	1996	1997
Flathead	*Neoplatycephalus richardsoni*		1994		1996	1997
	Platycephalus bassensis					
	Neoplatycephalus sp.					
Gemfish, Eastern	*Rexea solandri*		1994	1995	1996	1997
Gemfish, Western	*Rexea solandri*		1994			1997
Jackass Morwong	*Nemadactylus macropterus*		1994	1995		1997
John Dory	*Zeus faber*		1994		1996	1997
King Dory	*Cyttus traversi*			1995		
Pink Ling	*Genypterus blacodes*		1994	1995		
Mirror Dory	*Zenopisis nebulosus*		1994		1996	1997
Ocean Perch	*Helicolenus sp.*		1994		1996	
Orange Roughy	*Hoplostethus atlanticus*		1994	1995	1996	1997
Redfish	*Centroberyx affinis*	1993	1994	1995		1997
Royal Red Prawn	*Haliporoides sibogae*		1994			
School Whiting	*Sillago flindersi*		1994			
Silver Trevally	*Pseudocaranx dentex*		1994			
Silver Warehou	*Seriolella punctata*		1994			

5.2.3. Issues in the 1990s

The establishment of annual catch quotas (TACs) did not appear to constrain catches. Tilzey (1998) states:

> "With the exception of Eastern orange roughy, ling, and spotted warehou, the 1996 recorded catch totals of quota species were no more than 75 per cent of the TACs. For nine species, less than 50 per cent of the TAC was landed. For several species, catches have never exceeded 50 per cent of the TAC since ITQ management was introduced. There are a variety of possible explanations for this situation, ranging from biological reasons, such as a decline in stock abundance (i.e. the TAC is too high), to management/trading issues with allocation and transferability of quotas (i.e. quota is 'locked-up' and not being used to fish), to straightforward marketing issues (e.g. export demand for school whiting)." Tilzey (1998)

The assessment reports included biological reference points established by the management agency (AFMA), but these appeared to be reference years for comparison of recorded catch rates (CPUE). These reference points could only be used for those species for which unstandardised CPUE was available (Tilzey, 1998, 1999). This approach is similar to the current Tier 4 harvest control rule, which uses a defined reference period to act as a proxy for AFMA's current target proxy of 48%B_0.

In 1999, the stock assessment document (Tilzey, 1999) noted the development of new fishery models for Blue Warehou and Redfish. In addition, this was the first year that standardization of the catch rate data was undertaken for Blue Grenadier and for Blue Warehou (Haddon, 1998a, b).

From 1999 onwards there was an expansion of data collection under the Integrated Scientific Monitoring Program (ISMP). This provided for more age- and length-composition data from the catches and CPUE standardization. These data were used for integrated analyses using statistical catch at age assessment models.

5.2.4. Stock assessments, harvest strategies and testing

There were two Fisheries Research and Development Corporation (FRDC) funded projects relevant to the development of stock assessments and harvest strategies in the SEF. The first project related to the introduction of integrated analyses for some of the more important species in the SEF that hadn't already been assessed (Thomson and He, 2001). The second project examined potential harvest strategies and monitoring options for use in the SEF by developing an evaluation framework to test and compare alternative management strategies (Punt *et al.,* 2001).

Thomson and He (2001) developed new assessments for Blue Grenadier, Pink Ling, and Silver Warehou. This led to the development of other assessments, which eventually became the basis of the SESSF's current Tier 1 stock assessments and Harvest Control Rule (HCR). These assessments included model estimates of current spawning biomass and fishing mortality in relation to biological reference points. Punt *et al.* (2001) summarized the significance of what they did:

> "Assessment of SEF species continue to be based on the Integrated Analysis framework as the results of the evaluation of harvest strategies for four SEF species indicate that assessments of, and harvest strategies for, SEF species based on this framework perform best. The results are being used by SEFAG, industry and management to help decide how often assessments should be conducted and the key data collection / research needs. The results of the project have also increased interest by fishers and managers to select harvest strategies for SEF species and have further focused debate on the need for appropriately selected performance indicators. (Punt *et al.* 2001)

Up until 1999 there were still some species being assessed using the ADAPT-VPA (Virtual Population Analysis) form of assessment, but that approach requires an unbroken time-series of age-composition data from a fishery. With the expansion of monitoring to many more species, the time-series of data for some species were broken in some years. Statistical Catch-at-Age models (Integrated Analyses), can integrate the information available in an array of different data streams and do not require unbroken time-series. This prompted expansion of assessments to include Integrated Analyses.

In the early 2000s the Integrated Analyses used in fisheries stock assessment usually consisted of custom-written computer programs. User-friendly software packages for conducting age-structured analyses were generally unavailable. Fay (2004) used a package called 'Coleraine' (Hilborn *et al.,* 2003) to produce a new Integrated Analysis of the Jackass Morwong fishery.

5.2.5. A re-organization

By the end of 2002, there were 17 species (or species groups) under quota management (using TACs) within the SEF, with five species having their own assessment group (Orange Roughy – ORAG, Eastern Gemfish – EGAG, Blue Grenadier – BGAG, Blue Warehou – BWAG, and Redfish – RAG). Each assessment group was made up of scientists, fishers, managers and, in some cases, conservation members. Assessment groups usually met more than once each year to produce an annual stock assessment report based on a formal quantitative assessment model. There was also a separate SharkFAG that was concerned with the Southern Shark Fishery (SSF). This assessment group focused on gummy and school sharks. Each year quantitative assessments for some additional species were also carried out (for example, Eastern School Whiting, Pink Ling, and Silver Warehou).

In 2003, there was a restructure of the fisheries and their assessment processes which led to assessment groups being defined for groups of species instead of single species. This followed a change that grouped the various different fisheries into the umbrella SESSF. This change aimed to emphasise the EBFM system. The restructure of the assessment groups was undertaken to better reflect the ecosystem which supports the fishery. From 2003 there was the SESSF RAG (resource assessment group), the Shelf RAG, the Slope RAG, the Deepwater RAG and the Shark RAG.

The first of a series of annual stock assessment reports produced in the SESSF (Tuck and Smith, 2004) was the result of a FRDC-funded project (2001/005). The objectives of that project (defined in 2001) were to:

1. Provide new or updated quantitative assessments for SEF species based on SEFAG priorities.
2. Provide new or updated quantitative assessments for southern shark species based on SharkFAG priorities.

As stated in the resulting report:

> "The quantitative assessments produced annually by the Assessment Groups are a key component of the TAC setting process for the South East Scalefish and Shark Fishery. Prior to this report, the assessments were at a variety of stages of maturity and new species were regularly being added depending on Assessment Group priorities. To support the assessment work of the four Assessment Groups, the aims of the work conducted in this report were to develop new assessments, and update and improve existing ones for priority species in the SESSF." (Tuck and Smith, 2004)

This presents the use of annual quantitative assessments for setting the TACs in the SESSF. Previously, quantitative assessments were conducted regularly for some species, but only irregularly for others as deemed necessary by the SEFAG.

The new emphasis on EBFM was reflected in the first chapter of the next stock assessment report (Tuck, 2006; this time funded by AFMA), entitled 'Preliminary examination of annual trends in otter trawl targeting and catch diversity from the SEF1 logbook' (Klaer, 2006). In addition, Tuck (2006) also featured the first formal use of the modified catch-curves that became the basis of the current Tier 3 harvest strategy (Klaer and Thomson, 2006).

5.2.6. A harvest strategy for the SESSF

In the stock assessment report for the years 2005 – 2006 an important development was the introduction of a more formal harvest strategy. By the end of 2004, the use of TACs was the main management approach for the shelf, slope and deepwater species in the SESSF. However, the methods used to set TACs were not clearly defined and different approaches were used for different species. As stated by Wayte (2006):

> "Adopting agreed harvest strategies, including clear decision rules for setting TACs, would greatly improve certainty for all stakeholders in the management process, and if chosen wisely, should also lead to much better performance in achieving ESD objectives.
>
> The basic harvest strategy framework is being developed by a sub-set of SESSFAG, convened by Tony Smith and Paula Shoulder (Smith and Shoulder 2005). Major input to date has come from David Smith, with additional input from Ian Knuckey and Jeremy Prince.
>
> The framework will be road tested by the individual RAGs in June/July and endorsed by a full meeting of SESSFAG in August. Periodic updates on progress will be provided to AFMA and the MACs. It is intended that the harvest strategy framework will form the basis for SESSFAG advice to the MACs and the Board in September 2005." (Wayte 2006)

The Smith and Shoulder (2005) report was not published but the various Tier harvest control rules were used throughout the stock assessment report. However, descriptions of the harvest control rules and their structure for the Tier 1 and Tier 2 assessments were presented by Fay (2006) and those for the Tier 3 and 4 were described by Wayte (2006). The definitions of the four Tiers of assessment were eventually formally published as Smith *et al.* (2008) with a more recent update in Smith *et al.* (2014).

The limit and target reference points selected for the SESSF Harvest Strategy were dependent upon which tier was being considered. The Tier 1 assessments were robust quantitative assessments and had a target of B_{40}, which was 40% of unfished spawning biomass (B_0), a proxy for B_{MSY}. The limit reference point was B_{20} (half of the proxy for B_{MSY}). The target fishing mortality was F_{40} (the fishing mortality rate at which the stock will equilibrate at B_{40} in the absence of process and implementation error). For Tiers 3 and 4 proxies were developed to match these targets and limits. The target for Tier 2 (a less robust quantitative assessment) was set at B_{50}.

5.2.7. The Commonwealth Harvest Strategy Policy

At the end of 2005 the Minister for Fisheries (Macdonald, 2005) sent a letter to AFMA requiring them to: a) cease overfishing and recover overfished stocks to levels that will ensure long term sustainability and productivity; b) avoid further species from becoming overfished in the short and long term; and c) manage the broader environmental impacts of fishing, including impacts on threatened species or those otherwise protected under the *Environment Protection and Biodiversity Conservation* Act *1999*.

This led to a number of changes including the introduction of the Commonwealth Harvest Strategy Policy (HSP) and Guidelines (DAFF, 2007). There was also a structural adjustment package where vessel licences were bought out of Commonwealth fisheries so as to counter over-capitalization (and excess fishing effort) (too many vessels in the fleet). The structural adjustment occurred from November 2005 – November 2006 and the new HSP was applied to assessments towards the end of 2006 ready for implementing TACs in 2007. An important change to the SESSF harvest strategy was the adoption of a new target of maximum economic yield, with an agreed target reference point of 48%B_0 instead of 40%B_0. This led to a change in the Tier 1 HCR which in turn led to a reduction in most TACs.

The first assessments conducted using the new Commonwealth HSP were reported in Tuck (2007). These were conducted in 2006 typically using data to the end of 2005 to generate TAC advice for the 2007 fishing year. An important change was the introduction and use of the integrated stock assessment package 'Stock Synthesis 2' to conduct the Tier 1 stock assessments. This led to greater consistency between assessments and improved diagnostic outputs. Since then, all Tier 1 assessments (except those for shark species) have been conducted using a version of Stock Synthesis (Methot and Wetzel, 2013).

Management strategy evaluation (MSE) was used again to test the various HCR's associated with each Tier assessment (Wayte, 2009). This, plus experience with the initial Tiers, led to changes to both Tier 3 and Tier 4 assessments. The Tier 3 HCR was extended to include the use of length-based information only (Klaer *et al.,* 2012). The Tier 4 HCR was completely changed from that used in the 2007 assessment (Haddon, 2007; and Wayte, 2007) with the changes being formally described by Little *et al.* (2011).

The use of MSE to test the efficacy of the different Tier-related Harvest Control Rules and assessment methods was very important. The MSE established the effectiveness of HCR in avoiding the limit reference point (with the required probability) and further that the target species should move towards the target reference point. In the mixed fishery context of the SESSF it wasn't expected that all species would be able to achieve the specified target due to interactions between fisheries for different species. Nevertheless, the MSE testing demonstrated that the methods put in place would at the very least meet the limit reference point requirements of the Harvest Strategy Policy

5.2.8. Drivers for change

A number of factors prompted calls for changes in approaches to assessment of SESSF stocks from about 2010 onwards. Difficulties were being experienced with some assessments, with inadequate time in the busy annual assessment schedule to explore concerns about reliability of input data such as CPUE abundance indices or age-composition data. Widely conflicting results were being obtained between Tier 3 and Tier 4 assessments for a number of species, with little objective guidance as to the reliability of assessments.

The application of discount factors to Recommended Biological Catch (RBC) derived from Tier 3 and 4 assessments was increasingly being set aside in response to perceived reduced risk as a result of increasing spatial closures to protect overfished or otherwise vulnerable species. Most importantly, from 2010 onwards there was an increasing move towards rolling over of TACs and implementation of multi-year TACs (MYTACs), with substantial consequences for scheduling of stock assessments.

5.2.8.1. Application of discount factors

In recognition of the differences in certainty, and therefore in risk, between Tier 1, Tier 3, and Tier 4 assessments, it was recommended that appropriate discount factors be applied to explicitly introduce more precaution in TAC setting under the Tier 3 and Tier 4 harvest control rules. It was proposed that RBCs be discounted by 5% for Tier 3 species and by 15% for Tier 4 species. These discounts were the default ones that were to be applied, but the RAGs were requested to examine the need for their application on a species by species basis.

The discount factor control rule was introduced in 2009 and the SESSF RAG provided additional advice in 2011 on the application of discount factors (AFMA, 2012, Morison *et al.,* 2013), recommending that discount factors should apply to all Tier 3 and Tier 4 species except where:

- equivalent or additional precaution is provided by other measures, such as but not limited to spatial closures or markets limiting catch;
- long term stability in CPUE exists around current catch levels
  - RAGs will need to demonstrate long term stability of CPUE with CVs < 0.2 over an appropriate period based on the life history of the species; and,
  - RAGs need to consider the possibility that the observed stability may be due to other factors i.e. hyperstability.

These discount factors were not included in the management strategy evaluation (MSE) conducted when developing the Tier 3 and Tier 4 control rules, and so have not been tested. However, the MSE found that Tier 3 and Tier 4 without the discount factor met the requirements of HSP. Since 2009, RAGs have either applied the default 5% and 15% discount factors, or not at all. When discount factors were not applied, other measures such as closures were considered to be providing adequate protection.

Discount factors have been applied to relatively few of the Tier 3 and Tier 4 assessed stocks. Of the total 34 stocks assessed in the SESSF over the past decade, 16 have been Tier 3, 4, or most recently, Tier 5 stocks. Of these, discount factors were only applied to two Tier 3 and four Tier 4 stocks for 2015-16 and 2016-17 (Table 4). A further complicating factor is that Tier 4 assessments have either not been possible, or not accepted, for a number of species as a result of recent low catches making CPUE unreliable as an index of abundance. This has resulted in the recent introduction of data-poor Tier 5 assessments, such as the depletion-based catch analysis used for Smooth Oreo-other in 2015. Advice has not yet been provided on what discount factors might be appropriate for a Tier 5 assessment.

Table 4. Summary of application of discount factors to RBC recommendations for Tier 3 and Tier 4 species for the 2015-16 and 2016-17 fishing seasons.

Stock	Assessment Tier	Discount Factor
Alfonsino	3	5%
John Dory	3	5%
Mirror Dory	3	15%
Blue Eye Trevalla	4	0%
Blue Warehou	4	0%
Deepwater Shark East	4	0%
Deepwater Shark West	4	0%
Elephantfish	4	15%
Ocean Perch	4	15%
Oreo Basket	4	0%
Oreo Smooth Cascade	4	0%
Ribaldo	4	0%
Royal Red Prawn	4	0%
Sawshark	4	15%
Silver Trevally	4	0%
Oreo Smooth Other	5	0%
Discount applied		6
Discount not applied		10

Fay *et al.* (2012) provided an analysis of whether applicable discount factors, being the same for all species at a particular Tier level, achieve risk equivalency across the Tier framework, and whether alternative approaches might work better. The analysis revealed that discount factors required to obtain equivalent risk to the data-rich Tier 1 assessment varied with species and with stock status, and were different from the values used. More importantly, compared to the application of a discount factor, the alternative assessment methods tested could provide similar performance (with respect to stock biomass levels, TAC, and TAC variability) provided that the assessment methods and associated control rules were also adjusted to the equivalent level of risk as a Tier 1.

Fay *et al.* (2012) also found that stability in catch rates was not a reliable consideration for application of a discount factor, because either the same or higher discount factors were required to maintain risk at required levels, despite stable catches. Given these findings and the lack of an obvious alternative to the current approach, it was agreed to maintain arrangements for the application of discount factors for 2016-17. However, there is a need to determine risk equivalency when developing RBC advice using different assessment methods.

5.2.8.2. Conflicting Tier 3 and Tier 4 assessments

Comparative Tier 3 and Tier 4 assessments have been conducted for a number of SESSF stocks. This follows concerns about the reliability of either Tier 3 or Tier 4 assessments for certain species. Alternative methods could be considered if the required age-composition or CPUE data were available.

Three species assessed as Tier 3, John Dory, Mirror Dory and Redfish, revealed a conflict between apparently high stock status (as indicated by estimates of RBC above the $0.48B_0$ target level), and declining catches and decreasing CPUE over a period of many years. For these species, comparative Tier 3 and Tier 4 assessments were conducted from about 2012 onwards, all of which showed dramatic contrast between high (above target) Tier 3 stock status and low Tier 4 status, apparently below the $0.2B_0$ limit for redfish (Table 5) (AFMA 2011, 2012, 2013a, 2013b).

Table 5. Comparison of conflicting Tier 3 and Tier 4 RBC recommendations for John Dory, Mirror Dory and Redfish for 2012-13 to 2014-15, showing which assessment Tiers were used as the basis for TAC advice.

Stock	Season	Tier 3	Tier 4	Tier used
John Dory	2012-13	1,797	27	Tier 3
	2013-14	614	-	MYTAC
	2014-15	-	-	MYTAC
Mirror Dory	2012-13	7,349	557	Tier 3
	2013-14	2,794	-	Tier 3
	2014-15	-	680	Tier 4
Redfish	2012-13	1,569	0	Tier 3
	2013-14	2,932	0	Tier 3
	2014-15	3,791	0	Tier 4

These differences between assessments arose from poor fits to the descending limb of the catch-at-age data, resulting in under-estimation of total mortality (Z) and fishing mortality rate (F), and optimistic estimates of current stock status. The RAG considered the previous length-based Tier 3 assessment for Mirror Dory to be not robust because of unrepresentative length data and the previous RBC to be too optimistic. Despite improved age-composition data, the RAG maintained that the Tier 3 assessment was unreliable because of insufficient and unrepresentative age data.

These conflicts between alternative assessments have resulted in variable responses in terms of RAG advice regarding RBCs. RBC advice for all three species for 2012-13 was based on the Tier 3 assessments. For John Dory, the RAG noted that catch rates, although low, appeared to have been stable for some time, and that current catches were below the TAC. However, the RAG did not use either RBC estimate and instead, following industry input, recommended the conversion of the existing 2011-12 TAC of 221 t into a 3-year MYTAC for the next three seasons.

For Mirror Dory, RBC advice was based on Tier 3 assessments for 2012-13 and 2013-14, resulting (after deduction of State catches and application of the large-change limiting rule) in recommendations for increased TACs of 1077 t for 2012-13 and 1616 t for 2013-14. However, following rejection of the Tier 3 assessment in 2014 because of data limitations, the RAG used a Tier 4 assessment. This resulted in a decrease to the recommended TAC.

Although Redfish was assessed as a Tier 3 species, the RAG has taken Tier 4 results into account since 2011 following continually declining CPUE. Although catches had been declining since 1998 and CPUE had declined over a long period of time to a historically low level in 2012, this was not reflected in the Tier 3 assessments, with large fish apparently still present. Tier 4 assessments indicate biomass below the Limit Reference Point and continued decline. Redfish had previously shown variable availability and natural refuges may mean that a significant proportion of the stock are not vulnerable to trawling. This might explain the difference between assessments based on age composition versus those based on availability. The RAG advised that it was increasingly important that a Tier 1 assessment be completed. Pending this, Shelf RAG switched from Tier 3 to Tier 4 as the basis for RBC advice, and recommended a Tier 4 RBC of 0 tonnes for the 2014-15 season.

The substantially lower RBC estimates for these species from Tier 4 assessments, compared with Tier 3 assessments, negated the use of a higher discount factor for Tier 4 assessments. Of greater concern, the full schedule of annual assessments precluded the examination of reasons for these differences, or the development of guidelines for the selection of the most appropriate approach within the existing budget.

5.2.9. Implementation of multi-year TACs

Following the application of the Commonwealth HSP in the 2006 assessment round (Tuck, 2007), the number of species assessed under Tier 1, Tier 3 and Tier 4 increased and the size of the assessment reports increased. The Tier 1 assessments made up one volume whereas the CPUE standardizations, the Tier 3, and the Tier 4 assessments made up the second volume (e.g. Tuck, 2012a, b). This extra assessment activity led to increased costs and associated demands for cost reductions, prompted by reduced fishery profitability including ongoing under-caught TACs and a slow decline in the overall GVP of the fishery. This was despite positive and increasing net economic returns (NER) since the structural adjustment buy-back in 2006-07 (Skirtun and Green, 2015).

One option considered was to conduct stock assessments only every few years and implement multi-year TACs (MYTAC) to cover the intervening years. The first species to be explicitly considered for a MYTAC was Blue Grenadier, the most important species in the SESSF in terms of catch. This species displays episodic recruitment, with a pulse in recruitment in 1994 (estimated to be more than three times the long-term average) resulting in a rapid and substantial increase in biomass. This was followed by a number of years of poor recruitment and subsequent decrease in biomass (Tuck, 2013a, b). Rapid changes in biomass resulted in substantial changes in recommended RBCs and TACs, prompting calls to limit the magnitude of annual TAC changes. A preference was to fix TACs at some appropriate level for a number of years to promote the operational and economic stability of the fishery.

The first MYTAC was established in 2009 for Blue Grenadier for three seasons, from 2009-10 to 2011-12 (Table 6). Related to this, AFMA commissioned a review (Stokes, 2010) on guiding principles for implementation of MYTACs. Further consideration was undertaken by SESSF RAG on how best to implement such an approach (Tuck *et al.,* 2012). This consideration included the use of breakout rules to evaluate whether the MYTAC should be discontinued under certain specified circumstances (Klaer, 2012).

Table 6. Increase in the number of SESSF stocks subject to TAC rollovers or MYTACs per fishing season from 2009-10 to 2016-17. (1/3 - first year of a 3 year MYTAC; R - rollover of existing TAC; R> ongoing rollover until a catch trigger is reached).

Stock	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Blue Grenadier	1/3	2/3	3/3	1/2	2/2	1/3	2/3	3/3
Silver Warehou		1/3	2/3	3/3	1/3	2/3	3/3	1/3
Smooth Oreo non-Cascade			R>	R>	R>	R>	R>	1/3
Smooth Oreo Cascade			R>	R>	R>	R>	R>	R>
Gummy Shark			1/2	2/2	R	1/3	2/3	3/3
Tiger Flathead			1/2	2/2	R	1/3	2/3	3/3
School Whiting				R		R>	R>	R>
Bight Redfish				1/3	2/3	3/3	R	1/5
John Dory				1/3	2/3	3/3	1/3	2/3
Alfonsino				R		1/3	2/3	3/3
Deepwater sharks East					R	1/3	2/3	3/3
Deepwater sharks West					R	1/3	2/3	3/3
Deepwater Flathead						1/3	2/3	3/3
Gemfish West						1/3	2/3	3/3
Jackass Morwong						1/3	2/3	3/3
Mixed oreos						1/3	2/3	3/3
Ocean Perch combined						1/3	2/3	3/3
Ribaldo						1/3	2/3	3/3
Royal Red Prawn						1/3	2/3	3/3
Silver Trevally						1/3	2/3	3/3
Pink Ling						1/3		1/3
Orange Roughy East							1/3	2/3
Elephantfish								1/3
Sawshark								1/3
Blue eye Trevalla					R			
School Shark						Rebuilding strategy		
Redfish							Rebuilding	
OR Cascade Plateau		Rebuilding strategy - rollover incidental TAC						
Orange Roughy West / South		Rebuilding strategy - rollover incidental TAC						
Blue Warehou		Rebuilding strategy - rollover incidental TAC						
Gemfish East		Rebuilding strategy - rollover incidental TAC						
Stocks under	1	2	6	10	11	21	21	24
Rollovers / MYTACs	3%	6%	18%	29%	32%	62%	62%	71%

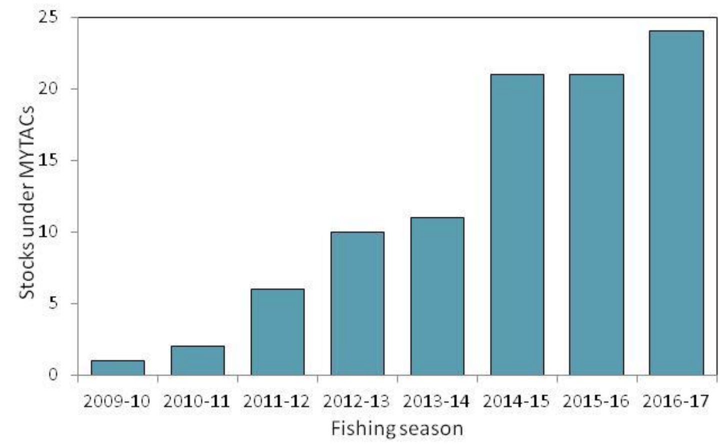


Figure 16. Increase in the number of SESSF stocks subject to TAC rollovers or placed under MYTACs per fishing season from 2009-10 to 2016-17 (see Table 6).

The implementation of specified MYTACs was preceded by rollovers of existing TACs for certain species. In some cases, such as for School Whiting or Smooth Oreos, this resulted from a decision by the RAG that, as circumstances had not changed, the TAC could be rolled over without increased risk. In other cases, such as for Alfonsino or Blue-Eye Trevalla, the rollover was necessitated by a lack of data to update assessments, or the unreliability of the available stock assessment.

Ad hoc consideration of TAC rollovers was replaced by explicit specification of a MYTAC period. In most cases, explicit MYTAC specifications have included the recommendation of a lower RBC, estimated from a Tier 1 assessment or from projections under constant catches and alternative control rules. This is considered to be sustainable and to pose low risk over the proposed MYTAC period. These MYTAC RBCs may be the estimated long-term yield, or an average of projected RBCs over the MYTAC period.

Of concern is the scheduling of assessments and inter-annual distribution of data analysis and assessment workload as a result of MYTAC implementation. Three-year MYTACs were simultaneously implemented for 15 stocks in 2014, potentially requiring 15 updated assessments in 2016. It is probably more practical to spread the assessment workload more evenly across years, particularly if there is an expectation that fewer assessments be conducted per year. This would also allow closer attention to certain assessments to resolve problems.

Another concern with MYTACs is that the harvest control rules (HCRs) for the various Tiers have been MSE tested on the basis of annual assessments. The reduction of RBCs for a three-year TAC (or more) to maintain the same low risk of avoiding the limit reference point requires evaluation. The SESSF RAG has supported the conduct of additional MSE work to examine the performance of control rules in achieving HSP objectives under MYTACs.

5.2.10. Review of the Commonwealth Harvest Strategy Policy

On 28 March 2012 the Minister for Agriculture, Fisheries and Forestry announced the review of the *Commonwealth Fisheries Harvest Strategy Policy and Guidelines 2007* (harvest strategy policy, DAFF, 2007). While, the HSP has been generally accepted as a successful initiative, there was an undertaking to review the policy within five years. This review was conducted by DAFF during 2012 and 2013 and coincided with a similar review of the *Commonwealth Policy on Fisheries Bycatch* (DAFF, 2013b).

The HSP Review Report (DAFF, 2013a) included recommendations relating to potential improvements in some technical aspects of the HSP, particularly of the HSP Implementation Guidelines. These recommendations for technical improvements derive from a substantial body of critical evaluation by Haddon *et al.* (2013a), Vieira and Pascoe (2013), Penney *et al.* (2013) and Ward *et al.* (2013).

Many of the recommendations relate to technical aspects relating to implementation of the revised policies. However, one key principle that emerged jointly from the reviews of the HSP and Bycatch Policies has immediate and substantial consequences for the present review of monitoring and assessment approaches in the SESSF. All species interacting with fisheries need to be included as part of the Harvest Strategy or the Bycatch Policy, and be monitored and managed according to the requirements of the respective revised policies. This will bring many byproduct or bycatch species previously only subject to periodic ERAs under management of one or other policy.

This review of the SESSF includes recommendations designed to reduce workload, reduce cost and improve the efficiency and cost-effectiveness of data collection and assessments. However, there is also a requirement to include a substantial number of additional minor by-product species in a revised HSP. This requires that a number of additional tasks:

- All of the species that interact with the SESSF need to be identified.
- Those identified species to be categorised as commercial (sometimes caught) or bycatch (seldom caught) species.
- The commercial species need to be categorized, potentially as Primary, Secondary and Minor Byproduct species, or at least key commercial and byproduct species.

- Guidelines need to be developed on how the species included under each of these categories should be monitored and assessed, and how species under each category should be managed to achieve the objectives of the respective policies.

Corrie *et al.* (2013) developed a system for categorisation of species, using the SESSF as the main test fishery. All species that had ever been observed, caught or landed in the SESSF were identified and listed from catch logbooks, catch disposal records, and observer report data. All available information on annual landed catches per species from 2007 to 2014, and first-sale prices per kg for each species from 2008-09 to 2014-15 was also included. Recent average annual catches and recent average prices were used to estimate average annual GVP and % GVP per species, providing a spreadsheet of all species ever recorded in the SESSF, with a number of quantitative measures per species that could be used to inform decisions on categorisation of species.

The resultant spreadsheet was updated by the addition of recent price information gathered by ABARES in preparation of the *2014 Australian Fisheries Economic Indicators Report* for the SESSF (Skirtun and Green, 2015). Alternative options for categorising species using GVP and catch information were evaluated. It was concluded that relative GVP contribution was the best indicator of economic importance to the fishery. This was used to categorise species as Primary Commercial species (required to be managed to an MEY target under the Commonwealth HSP).

For a mixed-species fishery such as the SESSF, the HSP provides for an overarching MEY target for the fishery which means that not all species will necessarily exist at their individual MEY biomass. Recognising this, the RAG allowed for secondary species (making low economic contribution to the fishery) to be managed to an MSY target. A number of species have been recently identified as secondary MSY-target species following guidance on such an approach by Vieira *et al.* (2013). For other categories, landed catch was considered to be the most important factor to distinguish between secondary species (which may be managed to an MSY target), minor byproduct and bycatch species.

A rule-based approach was incorporated into the spreadsheet, allowing the exploration of alternative GVP and catch cut-offs for categorising species between the Primary, Secondary, Byproduct and Bycatch categories. The catch and GVP cut-off levels shown in Table 7 are proposed for categorising species in the SESSF. These were chosen after consideration of the species that are currently assessed and managed as Tier 1, 3 or 4 species.

Table 7. Proposed catch and GVP cut-off levels for categorising SESSF species into management categories, number of species per category after applying these cut-offs, and proposed default reference point and assessment tier for each category.

Category	GVP %	Catch kg	No. of Species	Default Ref Point	Default Assessment
Primary	1.7%	(500,000)	11	MEY	Tier 1
Secondary	(0.5%)	110,000	20	MSY	Tier 4
Byproduct	(0.10%)	1,000	79	> Limit	Tier 5
Bycatch	(Rest)	Rest	560	> Limit	ERA

Note: GVP and Catch cut-offs function as alternative classifiers, with a species being allocated to a category of it exceeds EITHER the GVP OR the Catch cut-off for the category.

A total of 670 species or species groups have been recorded as being encountered in the SESSF since 2007. Of these, using the categorisation rules in Table 7, the top 11 species are classified as Primary Commercial species, the next 20 species are classified as Secondary species, 79 species fall into the category of Minor Byproduct, and the remaining 560 species are classified as Bycatch. The full categorisation of species is shown in Appendix 6: Proposed classification and assessment of SESSF species. The proposed Primary species category accounts for 77.1% of GVP and 71.0% of catch. Secondary species account for 16.2% of GVP and 20.1% of catch, with Minor Byproduct species accounting for 6.6% of GVP and 8.8% of catch. The 560 bycatch species account for only 0.2% of GVP and 0.1% of catch.

Table 7 also includes proposed default management targets and default assessment methods for the species categories, for use as a starting point for developing and evaluating alternative assessment approaches for the various species. It is likely that these defaults will be changed for some species, particularly those species for which the proposed assessment method is not feasible because of data or budget limitations. In particular, it is likely that most Minor Byproduct species will be evaluated using ERAs, and some Secondary species may need to be assessed under Tier 5.

5.3. Priorities, key concerns and opportunities for improvement in monitoring and assessment arrangements for the SESSF

Stakeholder views on concerns, priorities and opportunities for improvement in SESSF monitoring and assessment were canvassed in a workshop constituting a Reference Group for the project. The purposes of the workshop were to:

- Determine priorities, key concerns and perceived shortcomings in current monitoring and assessment arrangements for the SESSF; and
- Canvas stakeholder views on options for improvement in monitoring and assessment arrangements for the SESSF.

The first workshop was held in Canberra on 3 December 2014 and was attended by representatives from a wide range of affiliations and organisations. The outcomes of the workshop are summarised below, and the full report of the workshop, including the list of participants, is presented in Appendix 3: Report of the 1st Reference Group Consultation Workshop.

5.3.1. Characteristics of the SESSF

An overview of the key characteristics of the SESSF was presented at the workshop. The SESSF had been operating in a management environment where catch, effort, area fished and proportion of the available TAC caught in the SESSF were the lowest on record in 2013-14. A key priority for industry was to make monitoring and assessment arrangements more cost-effective, while still meeting policy requirements. Funding for monitoring, research and assessment could be set at a level relative to GVP and NER. Under the risk-catch-cost framework, research funding requirements are chosen to achieve an acceptable level of risk at particular catch levels, informed by advice from the existing RAG and MAC processes. Given the undercaught TACs and resulting lower risk, this trade-off could be re-evaluated to reduce monitoring and assessment costs for undercaught stocks. More efficient data collection activities should be considered to avoid duplication and to define more specifically the level of detail required.

5.3.2. Assessment of SESSF stocks

An overview of the current assessment process and links to fisheries management was presented to the workshop. Harvest strategies specify which data need to be collected for particular assessment approaches. The method of assessment applied to a stock has been dependent on the available data. Different levels of assessment are arranged as Tier levels, ranging from Tier 1 assessments (integrated statistical catch-at-age models) that are used for data rich stocks, to Tier 4 assessments (trends in standardised CPUE) that are used for stocks for which only catch, effort and CPUE are available. It was noted that the level of data collected for stocks can change over time due to alterations in catching methods, stock dynamics (biological productivity), areas fished, and data coverage, rendering some indices of abundance (such as CPUE) unreliable. This can result in difficulties in applying the chosen assessment methods for some stocks (current assessment methods for each species were decided on at the time of implementation of the SESSF Harvest Strategy Framework). This was particularly the case where there had been substantial spatial changes in the fishery (such as those resulting from spatial closures), which have resulted in increased assessment uncertainty. Ideally, spatially-structured models would be developed to account for this, but such models have higher requirements than currently available data. As a result, Tier 5 data-poor methods have recently had to be applied to species for which low catches and spatial changes have made CPUE and length-frequency data unreliable, leaving only catch data.

5.3.3. Management of the SESSF

An overview of the management process within the SESSF, and how monitoring and assessment is used to inform management, was presented to the workshop. Substantial effort is put into data collection, data management and reporting as part of an annual data requirements planning process. Resulting fisheries data provide the basis for stock assessments for target and by-product species, and ecological risk assessments for bycatch species. These analyses are presented and peer reviewed by RAGs which provide advice to MACs on RBCs. MACs in turn consider management options, including revisions to TACs, and advise the AFMA Commission, who make final decisions on management actions. Throughout this process, the implied risk-catch-cost trade-off is taken into consideration, to ensure that data collection costs are balanced against requirements to manage risks to stocks within the limits set by the HSP (across the range of information availability and assessment uncertainty at chosen assessment Tier levels).

The requirements of research and assessment in the SESSF have changed because of changes in management approaches and, while the move to MYTACs for key species has reduced the number of assessments each year, increasing spatial complexity of assessments for key species has increased the time and effort required to undertake assessments. The risk-catch-cost trade-off has received only preliminary MSE testing, although a project undertaken by CSIRO has provided further advice on discount factors and how the risk-catch-cost trade-off can be better implemented (Dichmont *et al*., 2016).

5.3.4. Requirements arising from the HSP and Bycatch Policy Reviews

The main recommendations arising from the 2013-14 reviews of the Commonwealth Harvest Strategy and Bycatch Policies were presented to the workshop. The presentation focused on requirements for assessment and management across the full range of species from target through secondary and minor by-product species to discarded bycatch and TEP species. The main implication of requiring assessment of all species, particularly by-product species, is the substantial increase in the number of stocks to be assessed. It also presents challenges in assigning different assessment categories (by relative importance to the fishery and by available data), what data to collect, how to assess stocks in each category, how to prioritise and schedule assessments, and what needs to be done about stocks that will not be assessed each year. This will require implementation of lower information assessment approaches, such as Tiers 5 – 7 outlined in Dichmont *et al.* (2013) (see Table 16). These lower levels do not produce estimates of relative biomass: Tier 5 produces relative estimates of *F*-based on spatial distribution of effort compared to species distribution; whereas Tiers 6 and 7 have no estimates of either B or F, instead using fishery dependent triggers and qualitative information for the fishery (or similar fisheries elsewhere) to demonstrate that the harvest strategy method has an acceptable level of risk.

5.3.5. Identification of priorities, key concerns and perceived shortcomings

Workshop participants were asked to identify concerns relating to the current monitoring and assessment approaches for the SESSF, and to identify suggested improvements. Participants raised 35 key concerns which were ranked in priority by the workshop (see Appendix 3: Report of the 1st Reference Group Consultation Workshop for methods used to identify and rank key concerns). Given the broad stakeholder representation, it is likely that all of the key concerns were identified. Notably, there was general consensus regarding important issues (receiving the highest scores), and which were minor or subsidiary issues (receiving no score). The Reference Group presented options to address the top ten nominated issues. Ranked key concerns expressed by workshop participants are shown in Table 8 and proposed suggestions to address these concerns are provided in the workshop report in Appendix 3: Report of the 1st Reference Group Consultation Workshop.

Table 8. First Reference Group Workshop: Summary of priorities and key concerns / perceived shortcomings. Proposed improvements to address these are shown in the table in Appendix 3: Report of the 1st Reference Group Consultation Workshop.

Score	Key concern / perceived shortcoming
31	Inadequate strategic planning of data collection, without clear specification of how data will be used
24	Data quality and quantity are insufficient to allow robust application of current assessment methods for many quota species, e.g. unreliable indices of abundance, inadequate age data
23	Don't understand environmental effects on fish stock productivity or availability, and not collecting the right data to do so
18	Need greater consistency in design and application of the SESSF HSF, e.g. tiers, discount factors, RCC, alignment of HS and ERA thresholds
18	Unclear whether FIS providing reliable indices of abundance for enough species to justify their continuation
17	Research and management costs too high and/or annually variable for small or under-caught fisheries
16	Application of MYTACs has not been MSE tested, resulting in reduced confidence in management under less frequent assessments
15	Inadequate information or certainty around levels of bycatches and discards
11	Increasing uncertainty around performance of rebuilding plans
11	Data collection planning does not adequately consider integration of data types, prevention of duplication of data collection or collection of unnecessary data or samples; are not collecting some data types
10	Unclear whether level of independent monitoring is adequate to provide reliable estimates of TEP species cumulative mortalities, particularly for multi-jurisdiction fisheries, and to assess resulting impact on populations
8	Concerns at inadequate collection of total catch (F) of stocks shared with other sectors or jurisdictions
8	Have not assessed whether observer data is representative of the fishery
7	Will current monitoring and data collection be adequate to detect early warning of declines to B_{lim} of additional species brought in under the HSP?
7	Incorporation of economic information and application of MEY approaches inadequate in multi-species fisheries
7	Concern that reference points established in the 1980s are not relevant to current stocks, notably B_{lim}; particular concern about now trying to apply this to additional species
7	Redesign of the monitoring and assessment will have to take account of articulation of acceptable levels of risk for bycatch species.
6	Low confidence in accuracy, adequacy or representativeness of biological data, e.g. outdated biological data
6	Inadequate collection of economic data
5	Difficulty of monitoring and quantifying underwater marine mammal interactions with gillnets
5	Is current monitoring adequate to detect spatial or temporal localised depletion?
5	Concerns that data are not adequate to capture spatial stock structure, and stock assessments not catering for actual spatial structure
4	Concern at insufficient knowledge of impact of fisheries on benthic ecosystems
4	Insufficient evaluation / explanation of the way that the precautionary principle is applied in assessments
3	Inadequate formal procedures or quality control of fisher-provided data
3	Research procurement has not been market tested to ensure cost-effectiveness
2	Inadequate integration and coordination between phases in the process: monitoring > data collection > data preparation > assessment
2	Social data / information currently not collected or used
1	Confusion around the application and meaning of the terms 'bycatch', 'tiers'
1	Assessments focus on retrospective analysis and trends; need more forecasting of longer term outlooks for fisheries
-	It is unclear what action should be taken when a 'breakout' rule or catch trigger is broken
-	FIS data are not integrated into the data systems and processes
-	Are under-caught TACs being adequately dealt with in subsequent stock assessments?
-	There are different levels of confidence in different data types from different sources
-	Initial allocation of species to assessment types was based on available data

6. Results and Discussion - Objective 2

6.1. Review of the SESSF Fishery Independent Surveys: Commonwealth Trawl Sector

Independent reviews of the CTS and GABT Fisheries Independent Surveys were commissioned under this project, and conducted by the National Institute of Water and Atmospheric Research (NIWA) in New Zealand. The full review report for the CTS FIS is presented in Appendix 7a. The terms of reference and a summary of conclusions are presented below.

6.1.1. Terms of reference

An independent expert review of the design, utility and effectiveness of FISs for providing fishery-independent indices of abundance for key commercial stocks in the SESSF; standardized commercial catch rates constitute the only other index of relative abundance currently available. This review evaluated and reported on:

1. Whether the FIS surveys are appropriately designed, for the given cost, to provide reliable abundance indices (with acceptable CVs) for the selected target species.
2. The frequency within which surveys could be conducted (considering the impact of within year CVs and between year variations).
3. Where FIS data have been used, perhaps in addition to the main objectives, and what were the benefits? If not immediately beneficial, at what stage is it reasonable to expect that the FIS might become more valuable?
4. Whether the FIS surveys have provided acceptably reliable indices for the selected target species for use in Tier 1 assessments.
5. Whether alternative approaches (such as standardised CPUE indices, species-targeted surveys) offer acceptably reliable alternatives to FIS surveys for generating reliable abundance indices.
6. Whether FIS is effective at monitoring for target and bycatch and suggest improvements or ‘add-ons’ to increase utility and provide additional benefits of broader value than providing abundance indices.
7. Whether the FIS survey is useful as a stand-alone assessment.
8. Whether FIS surveys should be continued or discontinued.
    - If FIS surveys are continued, what changes or improvements should be made to improve their usefulness?
    - If FIS surveys are discontinued, what are the implications for assessments, and what are the alternatives for fishery independent surveys?
9. Whether it is appropriate to split the FIS indices into east and west abundance estimates for Pink Ling, Jackass Morwong, Mirror Dory, Silver Warehou and Blue Warehou (at longitude 147° E), and deepwater shark (at latitude 42° S).

6.1.2. CTS FIS review outcomes

Provision of a Final Report presenting the results of a critical review of the CTS and GAB FIS surveys and recommendations regarding the future continuing, cessation, revision or improvements to the surveys to maximise utility of results.

6.1.3. Key conclusions of the CTS review

1. Two of the 11 main species have indices that appear to be reliable in terms of CV based on results to date: John Dory and Pink Ling. Gemfish (total) also appear to have reliable estimates, but as they are winter spawners that school off bottom, a bottom trawl survey may not be appropriate. Other main species appear to have either high estimated CVs (>30%) (Blue Warehou, Blue-eye, and Silver Trevally) and/or high inter-survey variability (Blue Warehou, Jackass Morwong, Tiger Flathead, Redfish, Mirror Dory, Silver Warehou). Some of this inter-survey variability may be explained by variation in, for example, recruitment (e.g., possibly Western Gemfish, Mirror Dory, and Tiger Flathead) and this will become more apparent as the time series and use of the data in assessment models develop. Although Jackass Morwong shows high inter-survey variability, the assessment shows a linear trend that may represent declining abundance.
2. Common Sawshark and King Dory may also be species that are relatively well monitored by the surveys due to acceptable CVs and process error.
3. For species that have abundance estimates with acceptable levels of precision and process error, stand-alone assessments could be conducted. However, stock assessment models, which include length frequency data, are likely to provide better understanding of inter-survey variability and would allow for predictions to be made.
4. Survey frequency should follow monitoring and management objectives (e.g., scale of change to be detected and acted upon) and fish biology (e.g., whether long- or short-lived species). Simulations suggest that the risk of potentially misleading results is reduced for an annual time series.
5. The value of such time series of surveys tends to increase over time, not only for individual species monitoring, but also for the development of additional indices for “environmental monitoring” (i.e., for bycatch species). Four surveys are insufficient to assess this potential adequately.
6. Alternative approaches include CPUE analyses and more specific species-targeted surveys. Alternative survey options were not examined as they appear cost-prohibitive for monitoring of the SESSF species. CPUE analyses have potential to monitor fishery performance, but are best used when the data have been validated to monitor abundance. Regular updates of CPUE analyses for some key species may be useful, in conjunction with surveys, to determine relative suitability over the longer term. The trawl survey time series is insufficient to make meaningful comparisons with CPUE trends (which are mostly presented on finer spatial scales).
7. It is not clear that the complicated “model-based design” was required, as some of the perceived problems with a randomized stratified survey design (RSS) could have been addressed by, for example, identification and removal of areas of foul ground from the survey area.
8. Acoustic measurements could be incorporated into the surveys to provide more information on inter-annual changes in vertical and areal availability of fish, by:
    - Independent estimates of total backscatter during the tows;
    - Estimates of total backscatter in between tows.
9. It is too early in the time series to make reliable decisions on whether they should be continued or not, and for which species time series may be most useful. To ensure that maximum value is obtained from continuing the series, therefore allowing for a more informed decision in the future, it would be useful to address the following:

- Which of the species are the demersal survey methods most appropriate for? For example, some species may be better assessed by alternative methods such as acoustic surveys;

- Minimising sources of variation in abundance indices (e.g., by calibration of the survey vessels against each other);
- Determination of factors affecting fish catchability and selectivity (in particular, seasonal changes in vertical and areal availability and aggregations; recording of maturity stage);
- More detailed examination of variability in size frequency and abundance indices (including CPUE) both spatially (including vertical distribution) and temporally, in relation to known stock distribution and movement and juvenile areas. This will be important if robust abundance indices are to be estimated for sub-regions.

6.2. Review of the SESSF Fishery Independent Surveys: Great Australian Bight

The full review report for the GAB FIS is presented in Appendix 7b. The terms of reference and a summary of conclusions are presented below.

6.2.1. Terms of reference

The terms of reference were the same as those for the CTS review (see above).

6.2.2. GAB FIS review outcomes

Provision of a Final Report presenting the results of a critical review of the FIS surveys and recommendations regarding the future continuing, cessation, revision or improvements to the surveys to maximise utility of results.

6.2.3. Key conclusion of the review

1. The random stratified survey design is appropriate to monitor the two target species, Deepwater Flathead and Bight Redfish. Good features include randomised positions, station allocation by strata, strata design based on CPUE, repeating the ground coverage and trip twice. The CVs are good and the process error appears to be modest. Overall the combined error is low enough for reliable monitoring. Deepwater Flathead indices make an important contribution to the assessment model. The fixed-site design may introduce some bias (if there are persistent strong local effects, or day/night effects), but reported CVs are probably appropriate.
2. Re-evaluation of stratum boundaries for the target species would be useful to determine if they are appropriate, as well as determination of optimal station allocation (e.g., as described by Francis, 2006). This may result in cost efficiencies by being able to reduce the number of stations required and, potentially, survey at night only.
3. Survey gear standardisation would be enhanced through the use of sensors to monitor bottom contact and gear spread (area swept). Recording echo sounder data can help inform interpretation of survey results (e.g., vertical availability to the gear). Problems with gear in the 2015 survey suggest that Trip 2 data only are best for assessment purposes.
4. The recent large decline in abundance of the target species (50% for Deepwater Flathead, 72% for Bight Redfish) suggests that a survey frequency of more than once every four years should be considered. The problems with the 2015 survey gear suggest that a repeat survey in 2016 would be beneficial (although there was no clear evidence of a lower catchability in that year). The cost of more frequent surveys may be able to be balanced, to some extent, against better optimised sampling (see #3 above). The appropriateness of survey timing was not evaluated.

5. The survey series is providing average CVs of less than 30% for the nine other main species (six had average CVs less than 20%), which is suitable for monitoring. Broader ecosystem monitoring would also appear to be feasible.
6. The two target species have abundance estimates with acceptable levels of precision and process error and stand-alone assessments could be conducted. However, stock assessment models, which include length frequency data, are likely to provide more understanding of inter-survey variability and would allow for predictions to be made.
7. CPUE analyses for Deepwater Flathead have high CVs, which make them a weak data series, and they appear to have limited value compared with survey abundance indices and age and length data. Bight Redfish were unable to be evaluated.
8. Surveys are providing useful abundance indices and should be continued, for target and associated species. Suggested improvements include optimisation of the design which should improve performance and decrease costs, and improved monitoring of net performance. Determination of factors affecting fish catchability and selectivity would also be beneficial.

6.3. Current monitoring and assessment for protected and recovering species

Key components of the current monitoring, assessment and management approaches implemented to meet policy requirements in relation to the reduction of impact on, and rebuilding of, protected and recovering species are summarised in this section. Data currently collected or generated that could potentially be used to address these needs are shown in **Error! Reference source not found.** and **Error! Reference source not found.**.

6.3.1. Memorandum of Understanding between the Australian Fisheries Management Authority and the Department of the Environment and Heritage for the Reporting of Fisheries Interactions with Protected Species under the *Environment Protection and Biodiversity Conservation* Act 1999

While this document contains no specific objectives, the MOU includes requirements to provide logbooks with specific fields concerning interactions with threatened, endangered, or protected species (TEPs), what information needs to be reported to DoE (formally DEH), how often (and what periods are covered) reports are to be provided, the requirement for reports to be made available on the DoE website, and that additional information on specific interactions may be requested.

Logbook TEP interactions are the only source of data used to inform reports of interactions that have occurred. The fields recorded in the current logbooks meet the MOU's requirements, and the timeframes for reporting allow the timely compilation of data and provision of reports.

In the MOU, AFMA states that "*Logbook data are not routinely independently verified. AFMA provides these data in good faith, but cannot attest to the accuracy of this data nor authenticate that this data is a complete record of all protected species interactions in the fishery*". This continues to be a limitation of recorded logbook interactions, and several studies have highlighted such problems (e.g. Knuckey and Stewardson, 2008; Knuckey and Koopman, 2011; Goldsworthy *et al.*, 2010; AFMA, 2013). Progress has been made in obtaining more complete reporting through education programs such as those by Knuckey and Stewardson (2008) and Boag *et al.* (2011), which led directly to increased reporting of seal interactions in the CTS (Knuckey and Koopman, 2011). Increases in observer coverage and the introduction of the Electronic Monitoring System (EMS) on Gillnet, Hook, and Trap vessels have also improved TEP reporting in the fishery AFMA (2013c). TEP reporting in the SESSF has changed since the 2005 agreement was made and, in particular, the implementation of EMS and / or 100% observer coverage in some sectors is used to routinely independently verify TEP interactions. In the case of EMS data, a proportion of the footage collected is reviewed and reported to AFMA for comparison with logbook interactions. Misreporting can then be followed up with compliance actions.

Despite evidence of under-reporting, use of logbook collection of TEP interaction data is cost effective, potentially covers 100% of the fishery and, importantly, logbooks provide the data needed for AFMA to fulfil its requirements under the MOU with the Department of the Environment and Energy. Logbook reporting has improved since implementation of EMS observation. Further improvements in the accuracy of the data could be made through a combination of regular education programs, comparison with observer and EMS coverage for each sector, as well as an effective enforcement program. Acknowledging this, SETFIA have worked with AFMA to produce E-learning modules that include sections on reducing and reporting TEP interactions.

Table 9. Data type collected or generated by various data programs. Grey ticks refer to programs that collect that type of data to a lesser extent.

	Data type requirements							
Data collection / generation program	**Length**	**Otoliths or vertebrae age**	**Catch of target species**	**Effort**	**By-product**	**Bycatch**	**TEP**	**Assessment of stock / ecological risk**
Daily fishing logbook / E-logs			✓ [5]	✓	✓ [6]	[7]		
Catch disposal records			✓		✓ [8]			
Logbook Interactions							✓	
State Fishery Logbooks			✓		✓			
Observer data	✓	✓	✓	✓	✓	✓	✓	
Fishery Independent Surveys	✓	✓	✓	✓	✓	✓	✓	
Industry collected length frequency data	✓							
Electronic Monitoring Systems (for verification)			✓	✓	✓	✓	✓	
Biological / stock structure studies / dedicated research projects / interaction and bycatch mitigation studies / survey of fishing gears	✓	✓	✓	✓	✓	✓	✓	
Ageing data		✓						
Stock assessment								✓
ERA								✓

5 Estimate only.
6 May not be accurate, particularly for lesser caught species because if weight caught for trip is less than 10 kg, it can be combined with other species of the same or less weight and reported as “mixed fish”.
7 It is sometimes recorded (particularly in the GABTS), but is not considered reliable
8 May not be accurate, particularly for lesser caught species because if weight caught for trip is less than 10 kg, it can be combined with other species of the same or less weight and reported as “mixed fish”.

Table 10. Data type collected / generated that address or could address different policy objectives. Key: ✔ currently used; ○ sometimes used; ▲ could be used.

		Policy													
		Target	**Bycatch**				**TEPS**				**Conservation programs/stock rebuilding strategies**				
	Data collection / generation program	**HSF**	**CTS BDW**	**GABTF BDW**	**ALF BWDW**	**SGF BDW**	**MOU**	**ASL MS**	**TAP 2014**	**GDMS**	**OR SRS**	**SS SRS**	**EG SRSR**	**BW SRSR**	**USD MS**
Logbooks	Shot catch – target species	✔									✔				
	Shot catch – byproduct species	✔									✔	✔	✔	✔	
	Shot catch – Bycatch														✔
	Shot effort	✔					✔	✔	✔	✔	✔	✔	✔	✔	✔
	Landed catch	✔									✔	✔	✔	✔	
	TEP interactions						✔	✔	✔	✔					
EMS	TEP interactions						○	✔	✔	✔					✔
	Shot effort / location	▲						✔	✔	✔	✔	✔	✔	✔	✔
Observer program	Shot catch – target species	✔													
	Shot catch – byproduct species	▲										✔	✔	✔	
	Shot catch – bycatch species	✔										✔	✔	✔	✔
	Shot effort	▲						✔	✔	✔		✔	✔	✔	✔
	TEP interactions							✔	✔	✔					
	Length	✔										✔	✔	✔	
	Age	✔										✔	✔	✔	
	Environment	▲						✔	✔	▲					
FISs	Shot catch – target species	✔									✔				
	Shot catch – byproduct species	✔										▲	✔	✔	
	Shot catch – bycatch species											▲	✔	✔	✔
	Shot effort	✔									✔	▲	✔	✔	✔
	TEP interactions														
	Length	▲									✔	▲	▲	▲	
	Age	▲									✔		▲	▲	
	Environment	▲										▲	▲	▲	
Ad hoc research	Shot catch – target species	○													
	Shot catch – byproduct species	▲										✔	✔	✔	

	Shot catch – bycatch species	○										✔	✔	✔	✔
	Shot effort	○						○	○	○		✔	✔	✔	✔
	TEP interactions							○	○	○					
	Length	○										✔	✔	✔	
	Age	○											▲	▲	
	Environment	▲							○			▲	▲	▲	✔
	Stock structure	✔									✔	✔	✔	✔	
	Bycatch mitigation												✔		✔
	TEP mitigation							○	○	○					
	Biological data	✔							○	○					✔
Co-/ Management	Reference points	✔									✔	✔	✔		✔
	Industry collected Length	✔												✔	

6.3.2. Australian Sea Lion (ASL) Management Strategy

The ASL Management Strategy aims to reduce the ecological risk the SESSF poses to Australian Sea Lions and enable their recovery by implementing long-term management measures including fisheries closures, as well as continuing to monitor and review the adequacy of management measures.

Research used to inform the ASL Management Strategy (MS) (e.g. Goldsworthy and Page, 2007; Goldsworthy *et al.*, 2009a; Goldsworthy *et al.*, 2009b; Goldsworthy *et al.*, 2010), and the need for future monitoring of ASL populations is highlighted in the Strategy. The ASL MS describes the need for a project to trial use of automatic longlines to target Gummy Shark that resulted in the project by Knuckey *et al.* (2014). Increased observer coverage was implemented as a result of the ASL MS to improve information on interactions between the gillnet sector and Australian sea lions and to assist in the development of the longer-term management strategy. In addition, observers modified their sampling protocol so that they watch the net emerging from the water during every shot they observe to identify ASL “drop outs”. VMS data are used to monitor fishing activities with respect to fishery closures. Logbook recorded TEP interactions are used to monitor the number of interactions in the fishery, and for implementing the adaptive management system. This management system has staged closures that result from ASL mortalities observed. EMS is used to verify reporting of TEP interactions. A proportion of the video footage is independently reviewed, and interactions compared with logbook TEP interactions. Logbook recorded fishing effort was used in research projects to model ASL bycatch and to determine the management regions used by the adaptive management system.

There is currently independent monitoring of 100% of gillnetting effort in waters offshore of South Australia. The number of Australian Sea Lion interactions reported by the GHaTS in 2013, 2014 and 2015 were 1, 0 and 2 (Commonwealth of Australia, 2016). Goldsworthy *et al.* (2010) estimated annual mortalities of more than 200 Australian Sea Lions from interactions with the GHaTS fishery at that time. Based on the large decrease in interactions, the susceptibility score of ecological risk assessments should be greatly reduced, reducing the estimate of ecological risk of the fishery to Australian Sea Lions. While there are no recent data demonstrating population recovery, the objectives of the ASL MS are being met because the ecological risk that the SESSF poses to Australian Sea Lions has been greatly reduced and this promotes their recovery.

6.3.3. Threat Abatement Plan (TAP) 2014 for the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations

The Seabird TAP 2014 aims to significantly reduce the seabird bycatch and bycatch rate during oceanic longline fishing operations in the Australian Fishing Zone through five key actions: mitigation; education; international initiatives; research, development and uptake; and innovation.

The Seabird TAP requires the collection of recorded logbook and observer TEP interactions and effort data (including descriptions of mitigation devices used), independent auditing of EMS data for use in verification of fishing effort, interactions and effectiveness of mitigation devices. Logbooks and eLogs are used to facilitate the accurate recording of: number of seabirds caught; species of seabirds caught; life status of seabirds caught; type of bait used; fishing gear and mitigation measures used and stage of operation when the seabird bycatch occurred; time of day/night of line setting and haul; date and location of the catch; and external factors (such as weather conditions and moon phase) that may influence seabird bycatch. Use of mitigation devices is reported by fishers in logbooks, and monitored using EMS and observers. TEP interactions recorded by observers and fishers in logbooks are monitored by AFMA, and trigger an investigation into inadequate or non-compliant implementation of mitigation measures and/or a lack of effectiveness of mitigation measures if more than one seabird was killed by a vessel in a trip. Observer and logbook TEP interaction and effort data are used to calculate interaction rates (called bycatch rate in the TAP 2014) to compare against the criterion (0.01 birds per 1000 hooks in each of the SESSF demersal longline sectors) for each fishing season. If this criterion is exceeded, a review must be undertaken of mitigation measures used in the fishery and other relevant circumstances (e.g. environmental conditions). The results of such a review will be used to guide assessment of the need for improved mitigation measures, and additional actions will be triggered if the criterion is exceeded in the next corresponding season. Total effort in the sector is reviewed annually using logbook effort data and a >20% change (increase or decrease) in effort may trigger a review of maximum permissible interaction rates. An annual review of all interaction data (logbook and observer) is undertaken to assess seabird bycatch levels by fishing area, season, fishery, and fishing method to monitor compliance with the criteria. The TAP describes the need for ongoing research and development of mitigation measures and devices, and for those to be tested against TAP criteria. The TAP also requires that all dead seabirds are retained.

The number of seabird interactions reported by the GHaTS in 2013, 2014 and 2015 was 18, 29 and 19 (Commonwealth of Australia, 2016). The primary goal of achieving a zero bycatch of seabirds, especially threatened albatross and petrel species, in all longline fisheries has not been met. Depending on the timeframe used, it would also seem that the overall objective of the TAP, of significantly reducing the seabird bycatch and bycatch rate during oceanic longline fishing operations, is not being met.

6.3.4. Upper-Slope Dogfish Management Strategy (USDMS)

The objective of the USDMS is to promote the recovery of Harrisson's Dogfish and Southern Dogfish through setting catch limits, area closures, setting reference points, estimating depletion, establishing rebuilding times, identification of Area and Network closure options using a MSE approach, determining extent of overlap of closures with dogfish habitat, and increased monitoring. These species were assessed to have been overfished as incidental bycatch in the Orange Roughy-targeted deepwater trawl fishery over the late 1980s - early 1990s.

The achievement of USDMS objectives requires a considerable amount of new information and analysis, obtained through additional research. Several research projects have been used to guide the Strategy including Williams *et al.,* (2012a, 2012b, and 2012c). Other research projects include identification of reference sites, identification of base-line numbers in reference sites, genetic analysis, life history analysis, and extent of movement. Vessel monitoring systems (VMS) are used by AFMA to monitor fishing activity in respect to area closures. Some closures are gear specific with interaction-trigger limits that rely on reporting by fishers in logbooks or observer data. Some closures also require 100% monitoring by either observers or with EMS. The USDMS recognises a range of potential indicators of recovery including the SESSF FIS, auto-longline or baited remote underwater video surveys, observer data, area of occupancy, sex ratio, size composition and genetic connectivity. A project to examine the feasibility of these, and of other options was submitted to the FRDC, although was not supported due to funding constraints. It was instead funded by the AFMA Research Committee and commenced on 1 May 2017 and is due for completion by 30 June 2018.

Implemented closures protect an estimated 16.2 — 25% of the core distribution areas of Harrisson's Dogfish and Southern Dogfish. However, there is no evidence yet available showing the recovery of those species. Given the biology of these species (they are relatively long lived with very low fecundity), recovery is expected to take decades. It is therefore still uncertain whether current management arrangements, including monitoring and assessment, are meeting the USDMS objectives.

6.3.5. Orange Roughy Stock Rebuilding Strategy (ORSRS) 2015

The primary objective of the ORSRS is to rebuild Orange Roughy stocks, overfished over the late 1980s - early 1990s, to levels where they can be harvested in an ecologically sustainable manner consistent with the *Commonwealth Fisheries Harvest Strategy Policy 2007* (HSP), to ultimately maximise the economic returns to the Australian community. The ORSRS applies TACs, area and depth closures, effort restrictions, reporting and monitoring and stock assessments.

Depth and area closures have been implemented, and VMS is used to monitor vessel activity with respect to closures. Annual TACs are set based on Tier 1 assessments. Data requirements for Tier 1 assessments include population parameters (relating to recruitment, maturity and growth), age composition, selectivity, indices of abundance from acoustic surveys and female spawning biomass estimates from an egg production survey, commercial logbook, commercial landings, and discard rates (although not included explicitly in the assessment Upston *et al.,* 2014).

To monitor any recovery of Orange Roughy stocks, biomass estimates are made using comprehensive acoustics surveys of well-defined spawning aggregations at periodic intervals in the Eastern Zone and on the Cascade Plateau. In other years, less precise methods such as opportunistic acoustic surveys, structured low-precision acoustic surveys and catch per shot are used to provide warnings of apparent large changes in biomass. Stock assessment models are to be updated every three years to provide information on stock status. In areas with no stable spawning aggregation, otoliths will be collected to evaluate stock status reflected in the age structures of unexploited and overexploited stocks at St Helen's Hill. Opportunistic trawl surveys, acoustic surveys, and catch per shot analyses are to be conducted for the GAB. Catch Data Records are used to monitor landing against TACs.

There have been no recent surveys or assessments of Orange Roughy in the GAB, southern zone, or western zone (Patterson *et al.,* 2015). It is therefore uncertain if current management, monitoring and assessments are meeting specified objectives. Following updated assessments using acoustic survey indications of increased biomass, the Stock Status of Orange Roughy at Cascade Plateau is now classified as "not overfished" and "not subject to overfishing" (Patterson *et al.,* 2015). Stocks in the eastern zone were shown by Upston *et al.* (2014) to have increased from the early 2000s to above the limit reference point. Consequently, a TAC of 500 t was set for the 2015–16, 2016–17 and 2017–18 fishing seasons (Patterson *et al.,* 2015). Based on the increased stock size in the eastern zone and maintenance of the Cascade Plateau stock above the target reference point, current management arrangements, including monitoring and assessment, are meeting the ORSRS objectives at least for those two stocks. Work is currently underway to ascertain whether the population recovery seen in these two stocks is likely to have also occurred in the GAB, southern and western stocks.

6.3.6. School Shark Stock Rebuilding Strategy 2008 and the School Shark (*Galeorhinus galeus*) Stock Rebuilding Strategy Revised (SSSRSR) 2015

The objective of the SSSRSR 2015 is to rebuild School Shark stocks in the area of the Southern and Eastern Scalefish and Shark Fishery to the limit reference biomass level within a biologically reasonable timeframe, and to continue rebuilding the stock towards the target reference point within a biologically reasonable timeframe. This is to be done through area closures, gear restrictions, catch limits, compliance, minimum length and processing standards, protection of pupping grounds, reduction of companion species catch and stock assessments.

Depth and area closures have been implemented, and VMS is used to monitor vessel activity with respect to those closures. The mesh size of nets used is specified to provide optimal selectivity to allow the escape of large females as well as small School Sharks, and the maximum number of hooks is restricted primarily to minimise the impact of this method on bycatch species. Mesh size and number of hooks set are recorded by observers and by commercial fishers in logbooks. Annual bycatch TACs are set for School Shark, based on the estimation of unavoidable incidental catch with a Gummy Shark TAC of approximately 1800 t, and an assessment consistent with stock recovery. CDRs are used to monitor landings against TACs. Assessment of the School Shark status is through stock assessment. However, with the active avoidance of School Shark and loss of a reliable CPUE index, there are problems in obtaining an index of abundance to inform assessments. The stock assessment uses historical indices of abundance, pup survey data, ISMP data, population parameters (such as recruitment, maturity and growth), mean size, sex ratio, tag and release, commercial logbook and commercial landings (Thomson and Punt, 2009; Thomson, 2012).

The specified timeframe for re-building School Shark stocks to above the limit reference point is three times the mean generation time. This is about 66 years, and starting at 2008 the target year is 2074. The most recent assessment indicated that the limit reference point will likely be reached before the target year based on current catches (Thomson, 2012). However, there is some uncertainty in the assessment (Patterson *et al.,* 2015). There are additional, multiple lines of evidence suggesting that the stock is increasing including: trawl CPUE, IMAS pup surveys, ISMP data and anecdotal reports from Industry (Patterson *et al.,* 2015). Based on these results, current management, monitoring and assessments are likely to be meeting the objectives of the SSSRSR 2015.

6.3.7. Eastern Gemfish Stock Rebuilding Strategy 2008 and Eastern Gemfish (*Rexea solandri*) Stock Rebuilding Strategy Revised (EGSRSR) 2015

The objectives of the EGSRSR 2015 are to rebuild Eastern Gemfish stocks to the limit reference point within a biological reasonable timeframe, then continue rebuilding stocks towards the target reference point and pursue a biomass level of B_{MEY}. The strategy is designed to achieve this by setting a low annual incidental catch TAC; fishing gear restrictions; limited entry; fishery closures; collecting observer data on discards, length composition and otoliths; fishery-independent surveys; trip limits; education; monitoring of location and time of capture for potential spatial and temporal closures; and investigating use of EMS to supplement the observer program.

Minimum codend mesh size and bycatch reduction devices are mandatory, and their use is recorded both by fishers (in logbooks) and by observers. Incidental catch TACs are set and reviewed annually. CDRs are used to monitor landings in relation to the TAC during each fishing season. Discards are monitored by observers. Additional observer effort is focused in areas and times of high Eastern Gemfish abundance to obtain improved length data, otolith samples and discard estimates. The SESSF FIS may provide an index of relative abundance that could be used in stock assessments, despite a high CV. Over time, surveys may be able to detect large changes in abundance. The latest Tier 1 stock assessment was conducted for Eastern Gemfish in 2010. Data used included: logbook catch and effort data; discards, lengths and otoliths from observers; age composition and an age-reading error matrix from FAS; and landed catch from CDRs. Eastern Gemfish have also been assessed using the spawning potential ratio (SPR) analysis which uses outputs from the SS3 model, and so has the same data requirements as a Tier 1 model (Little, 2012).

The specified timeframe for re-building Eastern Gemfish stocks to above the limit reference point is one mean generation time plus 10 years (Patterson *et al.,* 2015) This is about 19 years and, starting at 2008, the target year is 2027. The most recent estimate of spawning stock biomass indicated that stocks were recovering, and were at 15.6% of the 1968 level in 2008 (Little and Rowling, 2011, cited in Patterson *et al.,* 2015). Using SPR analysis, Little (2011) found that, based on assessment model projections, the Eastern Gemfish stock should reach the limit reference point by 2025. Based on these results, current management, monitoring and assessments are meeting the objectives of the EGSRSR 2014. However, estimated projections assumed average levels of recruitment and that total removals will be limited to 100 t (Patterson *et al.,* 2015).

6.3.8. Blue Warehou (*Seriolella brama*) Stock Rebuilding Strategy Revised (BWSRSR) 2014

The objectives of the BWSRSR 2014 are to rebuild Blue Warehou stocks to the limit reference point within a biological reasonable timeframe, then continue rebuilding stocks towards the target reference point, B_{MEY}. It is designed to achieve this by setting a low annual incidental catch TAC, selective fishing gear, limited entry, fishery closures, monitoring and enforcing closures, catch triggers and increased data collection through fishery independent surveys, the observer program, industry collected data, and EMS.

A voluntary spatial closure was implemented to reduce incidental Blue Warehou catch, and VMS was used to monitor vessel activity with respect to the closure. This closure has since been removed due to lack of fishing effort and RAG advice that it was no longer required as a means of protecting the stock. Minimum codend mesh size and, in most cases, bycatch reduction devices have been applied in the CTS, with gillnet mesh size between 15–16.5 cm. Gear used is recorded by fishers in logbooks and by observers. Annual incidental catch TACs are set after consideration of the ability of stocks to rebuild by 2024, the likely quantity of incidental catch based on landed catch, discard estimates in logbooks and observer discard data, as well as advice from ShelfRAG and / or SEMAC. There are catch triggers for the eastern and western stock. Industry reporting arrangements (call-ins / email for catches of 250 kg or more) are in place to track catches during the seasons and, once 60% of each trigger is reached, fishers will be asked provide details of total catches of Blue Warehou which will be then reconciled against total tonnages recorded by AFMA. There is more regular reporting as the annual catch limits are reached and, when reached, all landing of Blue Warehou must cease for that zone. In addition, catch reports (CRDs) for both zones are monitored on a quarterly basis. As a result of the loss of data due to reduced catches, Tier 1 assessments are no longer considered to be robust for this species. Therefore, Blue Warehou was then assessed as Tier 4 using CPUE from commercial logbooks, although this is also no longer considered reliable because of fisher avoidance. SPR analysis to assess the status of Blue Warehou stocks has been considered. However, that method uses outputs from the SS3 model and has the same data requirements as a Tier 1 assessment.

Discard information, length data, and otoliths are collected by observers. The SESSF FIS may provide an index of relative abundance that could be used in stock assessments but there is concern about the level of interannual variation in these estimates. Over time, surveys may have the ability to detect any large changes in abundance. Industry members collect Blue Warehou length frequency data to supplement observer collections and these data will be incorporated into future assessments, as and when feasible.

The specified timeframe for re-building Blue Warehou stocks to above the limit reference point is one mean generation time plus 10 years. This is 16 years and, starting at 2008, the target year is 2024. Based on Tier 4 analysis, both eastern and western stocks of Blue Warehou are substantially below limit reference points and have not shown any signs of recovery (Haddon, 2013, cited in Patterson *et al.,* 2015). However, it was noted by Patterson *et al.*, (2015) that because of the introduction of quota management, the rebuilding strategy, and efforts by SETFIA and AFMA to reduce targeting, changes in CPUE are unlikely to accurately reflect changes in biomass. There have been two Blue Warehou surveys which aimed to record targeted catch rates that could be compared to historical catch rates (Hudson and Knuckey, 2006; Knuckey *et al.*, 2012). However, variability and uncertainty in the timing of Blue Warehou aggregations resulted in conflicting and unreliable results. Based on this, it is uncertain if current management, monitoring and assessments are meeting the objectives of the BWSRSR 2014.

6.4. Operational Policy Documents

This section provides an overview of the AFMA operational policy documents for the SESSF, being: the Orange Roughy Stock Rebuilding Strategy 2014; School Shark Stock Rebuilding Strategy 2008; Eastern Gemfish Stock Rebuilding Strategy 2008 and draft Eastern Gemfish (*Rexea solandri*) Stock Rebuilding Strategy Revised 2014; Blue Warehou (*Seriolella brama*) Stock Rebuilding Strategy 2008 (Revised April 2012) and draft Blue Warehou (*Seriolella brama*) Stock Rebuilding Strategy Revised 2014; Commonwealth Trawl Sector (Otter Board Trawl & Danish Seine) Bycatch And Discarding Workplan; Great Australian Bight Trawl Fishery Bycatch And Discarding Workplan; Automatic Longline Fishery Bycatch And Discarding Workplan; Shark Gillnet Fishery Bycatch And Discarding Workplan; MOU Between the Australian Fisheries Management Authority and the Department of the Environment and Heritage for the Reporting of Fisheries Interactions with Protected Species Under the *Environment Protection and Biodiversity Conservation* Act 1999; Commonwealth Fisheries Harvest Strategy Policy and Guidelines; Australian Sea Lion Management Strategy; Threat Abatement Plan 2014 for the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations (Threat Abatement Plan 2); Gillnet Dolphin Mitigation Strategy; and the Upper-Slope Dogfish Management Strategy. Policies and relevant objectives are summarised in Table 11 for each Species Group.

Table 11. Policies and relevant objectives for each Species Group (involving capture or interaction in the SESSF.

Species Group	Policy	Objectives related to fishery component
Target species	Harvest Strategy Framework for the Southern and Eastern Scalefish and Shark Fishery	The objectives of the HSF include: Biological - to maintain stocks at (on average), or return to, a target biomass point B_{TARG} or equivalent proxy (e.g. F_{TARG} or $CPUE_{TARG}$) equal to the stock size that aims - to maximise net economic returns for the fishery as a whole; - to maintain stocks above the limit biomass level, or an appropriate proxy, at least 90% of the time; - to progressively reduce the level of fishing if a stock moves below B_{MSY} and towards B_{LIM} (or an appropriate proxy); - to implement rebuilding strategies, no-targeting and bycatch TACs if a stock moves below B_{LIM} (or an appropriate proxy). - to ensure the sustainability of fisheries resources, including consideration of the individual fishery circumstances and individual species or stock characteristics, when developing a management approach; Socio-economic - to maintain stocks at (on average), or return to, a target biomass point B_{TARG} equal to the stock size that aims to maximise net economic returns for the fishery as a whole
	Orange Roughy Stock Rebuilding Strategy 2014	To conserve Orange Roughy to ensure its long term survival in nature and recover the species to ecologically sustainable levels.
	Commonwealth Trawl Sector (Otter Board Trawl & Danish Seine) Bycatch and Discarding Workplan	To reduce discarding of target and non-target species to as close to zero as practically possible;
	Great Australian Bight Trawl Fishery Bycatch and Discarding Workplan;	Develop strategies that will: -reduce discarding of target species to as close to zero as practically possible;
	Automatic Longline Fishery Bycatch and Discarding Workplan	To reduce discarding of target species to as close to zero as practically possible
Bycatch	Harvest Strategy Framework for the Southern and Eastern Scalefish and Shark Fishery	The objectives of the HSF include: Ecosystem - to be consistent with the principles of ecologically sustainable development, including the conservation of biological diversity, and the adoption of a precautionary risk approach.
	Commonwealth Trawl Sector (Otter Board Trawl & Danish Seine) Bycatch and Discarding Workplan	Develop strategies that will: - reduce the number of high risk species as assessed through AFMA's Ecological Risk Assessment process; - reduce discarding of target and non-target species to as close to zero as practically possible; and - minimise overall bycatch in the fishery over the long-term.
	Great Australian Bight Trawl Fishery Bycatch and Discarding Workplan;	Develop strategies that will: - respond to high ecological risks assessed through the Australian Fisheries Management Authorities (AFMA's) Ecological Risk Assessment Process; facilitate assessment for the Effect of Fishing (ERAEF) and other assessment processes; - minimise overall bycatch in the fishery over the long-term
	Automatic Longline Fishery Bycatch and Discarding Workplan	Develop strategies that will: - address high ecological risk species identified through AFMA's ERA process; quantify and minimise overall levels of bycatch in the fishery.

	Shark Gillnet Fishery Bycatch and Discarding Workplan;	The key objectives are to: - respond to key high risk species and take steps to increase the knowledge of all high-risk species and their interactions with the fishery; - develop a longer-term response plan for all remaining high risk species based on scientific advice; - ensure through independent monitoring that robust estimates of discarding are made and used in the harvest strategy for the GHATS.
TEPs	Harvest Strategy Framework for the Southern and Eastern Scalefish and Shark Fishery	The objectives of the HSF include: Ecosystem - to be consistent with the principles of ecologically sustainable development, including the conservation of biological diversity, and the adoption of a precautionary risk approach.
	Commonwealth Trawl Sector (Otter Board Trawl & Danish Seine) Bycatch and Discarding Workplan	To reduce the number of high risk species as assessed through AFMA's Ecological Risk Assessment process; To avoid interactions with species listed under the *Environment Protection and Biodiversity Conservation* Act 1999 (EPBC Act);
	Great Australian Bight Trawl Fishery Bycatch and Discarding Workplan;	Develop strategies that will: - respond to high ecological risks assessed through the Australian Fisheries Management Authorities (AFMA's) Ecological Risk; facilitate assessment for the Effect of Fishing (ERAEF) and other assessment processes; - avoid interactions with species listed under the *Environment Protection and Biodiversity Conservation* Act 1999 (EPBC Act);
	Automatic Longline Fishery Bycatch and Discarding Workplan	Develop strategies that will: - address high ecological risk species identified through AFMA's ERA process; address interactions with species listed as TEP under the *Environment Protection and Biodiversity Conservation* Act 1999 (EPBC Act)
	Shark Gillnet Fishery Bycatch and Discarding Workplan;	The key objectives are to: - develop measures to mitigate interactions with TEP species
	MOU Between the Australian Fisheries Management Authority and the Department of the Environment and Heritage for the Reporting of Fisheries Interactions with Protected Species Under the *Environment Protection and Biodiversity Conservation* Act 1999	While no specific objectives are listed in the MOU, it was established to streamline the reporting requirements for fishers interacting with species protected under the *EPBC* Act.
	Australian Sea Lion Management Strategy	The specific objectives of the strategy are to significantly reduce the ecological risk the SESSF poses to Australian Sea Lions and enable their recovery.
	Threat Abatement Plan 2;	The goal of the TAP is to achieve a zero bycatch of seabirds, especially threatened albatross and petrel species, in all longline fisheries. The objective of the TAP is to continue to significantly reduce the seabird bycatch and bycatch rate during oceanic longline fishing operations in the Australian Fishing Zone.
	Gillnet Dolphin Mitigation Strategy	This Strategy aims to minimise the bycatch of dolphins in gillnets in the SESSF to as close to zero as possible. To achieve this, the short-term objective of this Strategy is for each gillnetting boat to adopt the measures best suited to their individual operation to minimise their risk of bycatch.

Byproduct	Harvest Strategy Framework for the Southern and Eastern Scalefish and Shark Fishery	The objectives of the HSF include: Ecosystem - to be consistent with the principles of ecologically sustainable development, including the conservation of biological diversity, and the adoption of a precautionary risk approach.
	Commonwealth Trawl Sector (Otter Board Trawl & Danish Seine) Bycatch and Discarding Workplan	Develop strategies that will: - reduce the number of high risk species as assessed through AFMA's Ecological Risk Assessment process; - reduce discarding of target and non-target species to as close to zero as practically possible; and - minimise overall bycatch in the fishery over the long-term.
	Great Australian Bight Trawl Fishery Bycatch and Discarding Workplan;	Develop strategies that will: - respond to high ecological risks assessed through the Australian Fisheries Management Authorities (AFMA's) Ecological Risk; - facilitate assessment for the Effect of Fishing (ERAEF) and other assessment processes; - minimise overall bycatch in the fishery over the long-term
	Automatic Longline Fishery Bycatch and Discarding Workplan	Develop strategies that will: - address high ecological risk species identified through AFMA's ERA process; quantify and minimise overall levels of bycatch in the fishery.
	Shark Gillnet Fishery Bycatch and Discarding Workplan;	The key objectives are to: - respond to key high risk species and take steps to increase the knowledge of all high-risk species and their interactions with the fishery; develop a longer-term response plan for all remaining high risk species based on scientific advice; - ensure through independent monitoring that robust estimates of discarding are made and used in the harvest strategy for the GHATS.
Communities and habitat	Harvest Strategy Framework for the Southern and Eastern Scalefish and Shark Fishery	The objectives of the HSF include: Ecosystem - to be consistent with the principles of ecologically sustainable development, including the conservation of biological diversity, and the adoption of a precautionary risk approach.
	Commonwealth Trawl Sector (Otter Board Trawl & Danish Seine) Bycatch and Discarding Workplan	Develop strategies that will: - reduce the number of high risk species as assessed through AFMA's Ecological Risk Assessment process
	Great Australian Bight Trawl Fishery Bycatch and Discarding Workplan;	Develop strategies that will: - respond to high ecological risks assessed through the Australian Fisheries Management Authorities (AFMA's) Ecological Risk; - facilitate assessment for the Effect of Fishing (ERAEF) and other assessment processes
	Automatic Longline Fishery Bycatch and Discarding Workplan	Develop strategies that will: - address high ecological risk species identified through AFMA's ERA process
	Shark Gillnet Fishery Bycatch and Discarding Workplan;	The key objectives are to: - respond to key high risk species and take steps to increase the knowledge of all high-risk species and their interactions with the fishery; - develop a longer-term response plan for all remaining high-risk species based on scientific advice; - develop measures to mitigate interactions with TEP species; and ensure through independent monitoring that robust estimates of discarding are made and used in the harvest strategy for the GHATS.
Conservation dependent	Harvest Strategy Framework for the Southern and Eastern	The objectives of the HSF include: Biological

	Scalefish and Shark Fishery	- to implement rebuilding strategies, no-targeting and bycatch TACs if a stock moves below B_{LIM} (or an appropriate proxy). - to ensure the sustainability of fisheries resources, including consideration of the individual fishery circumstances and individual species or stock characteristics, when developing a management approach; Socio-economic - to maintain stocks at (on average), or return to, a target biomass point B_{TARG} equal to the stock size that aims to maximise net economic returns for the fishery as a whole;
	Orange Roughy Stock Rebuilding Strategy 2014	To conserve Orange Roughy to ensure its long-term survival in nature and recover the species to ecologically sustainable levels.
	School Shark Stock Rebuilding Strategy 2008	Following the formulation of the Commonwealth Fisheries Harvest Strategy Policy, the objectives of this rebuilding strategy are: - to rebuild school shark stocks in the area of the Southern and Eastern Scalefish and Shark Fishery to the limit reference biomass level - B_{20} within a biologically reasonable timeframe. - having reached B_{20} rebuild School Shark stocks in the area of the Southern and Eastern Scalefish and Shark Fishery to the target biomass level - B_{40} (the default B_{MSY} point contained in the Commonwealth Fisheries Harvest Strategy Policy) within a biologically reasonable timeframe (a 'typical' biologically reasonable time is 10 years plus one mean generation time and one mean generation time for School Shark = 20 to 25 years).
	Eastern Gemfish (*Rexea solandri*) Stock Rebuilding Strategy Revised 2014	Consistent with the Fisheries Management Act 1991 (the Act) the broad objective of the Strategy is to return Eastern Gemfish stocks to ecologically sustainable levels and ultimately maximise the economic returns to the Australian community from the resource. In line with the HSP there are three rebuilding objectives: - to rebuild Eastern Gemfish in the area of the SESSF to the default limit reference level of 20% of unfished spawning stock biomass (B_{LIM}) within a biologically reasonable time frame, being approximately 19 years (one mean generation time plus 10 years). - having reached B_{LIM}, rebuild Eastern Gemfish to the maximum sustainable yield level of 40% of unfished spawning stock biomass (B_{MSY}). Once B_{MSY} is reached, pursue the biomass level which aims to maximise net economic returns, currently 48% of unfished spawning stock biomass (B_{MEY}).
	Blue Warehou (*Seriolella brama*) Stock Rebuilding Strategy Revised 2014	To rebuild Blue Warehou (east and west) stocks in the area of the SESSF to or above the default limit reference biomass point (B_{LIM}) of 20% of the unfished spawning biomass within a biologically reasonable time frame; one mean generation time plus 10 years (approximately 16 years). That is, to reach or exceed B_{LIM} by no later than 2024. Having reached B_{LIM}, rebuild Blue Warehou (east and west) stocks in the area of the SESSF to the default maximum sustainable yield biomass level of 40% of the unfished spawning biomass (B_{MSY}) using the harvest control rules outlined in the SESSF Harvest Strategy Framework. Once B_{MSY} is reached, pursue the biomass level which aims to maximise net economic returns, currently 48% of unfished spawning biomass (B_{MEY}).
	Upper-Slope Dogfish Management Strategy	The objective of the Strategy is to promote the recovery of Harrisson's Dogfish and Southern Dogfish.

7. Results and Discussion - Objective 3

7.1. Monitoring tools

The SESSF has a sophisticated system of fisheries monitoring in place across the various sectors of the fishery to support management, and to provide the data inputs necessary to conduct various assessments (Table 12). Fishers record details of their fishing operations and catches in logbooks, and accurate weights of catch for each trip in catch disposal records (CDRs). The Integrated Scientific Monitoring Program (ISMP) includes an onboard observer program to record estimates of retained and discarded catch and interactions with TEP species, together with biological data including length frequency measurements, and the collection of otoliths and shark vertebrae. The ISMP also has dedicated port-based data collection to collect length-frequency and otoliths from the landed catch.

Ongoing FISs in the areas of the GABTS and CTS provide estimates of relative biomass for a number of quota and non-quota species. Specific forms of FIS have been developed for Orange Roughy and for Blue Grenadier that use a CSIRO-developed Acoustic Optical System (AOS) to collect snapshot biomass estimates of spawning aggregations. E-monitoring cameras are in place for the GHaTS, primarily to monitor interactions with TEP species, although these also have the potential to collect length frequency data. The GABTS has a successful project using crew member observers to collect length frequency data on the retained catch of the most common quota species. A summary of the monitoring tools used in the fishery and the data they provide is shown in Table 12 and the timing and flow of data collection is depicted in Figure 17. Further details on each of the monitoring tools are provided below.

Table 12. Monitoring tools and data sources in the SESSF

SESSF Data Sources	Logbooks	CDR	ISMP - Onboard	ISMP - Port	EMS	FIS	AOS	Crew observers	Research
Date-Time	✓	✓	✓	✓	✓	✓	✓	✓	
Position	✓		✓	✓	✓	✓	✓	✓	
Depth	✓		✓			✓	✓		
Effort	✓		✓			✓			
Total Catch			✓			✓			
Retained Catch	✓		✓		✓				
Discarded Catch	✓		✓		✓				
Commercial CPUE	✓		✓						
Independent CPUE						✓	✓		
Landed Catch		✓			✓				
Retained Weight	✓		✓						
Discarded Weight	?		✓						
Retained L-freq			✓	✓	?	✓		✓	
Discarded L-Freq			✓						
Otoliths			✓	✓		✓	✓		
Detailed Bycatch			✓			✓			
TEP Interactions	✓		✓		✓	?			
Age / Growth									
Maturity / Fecundity									
Mortality									
Selectivity									
Bycatch reduction									

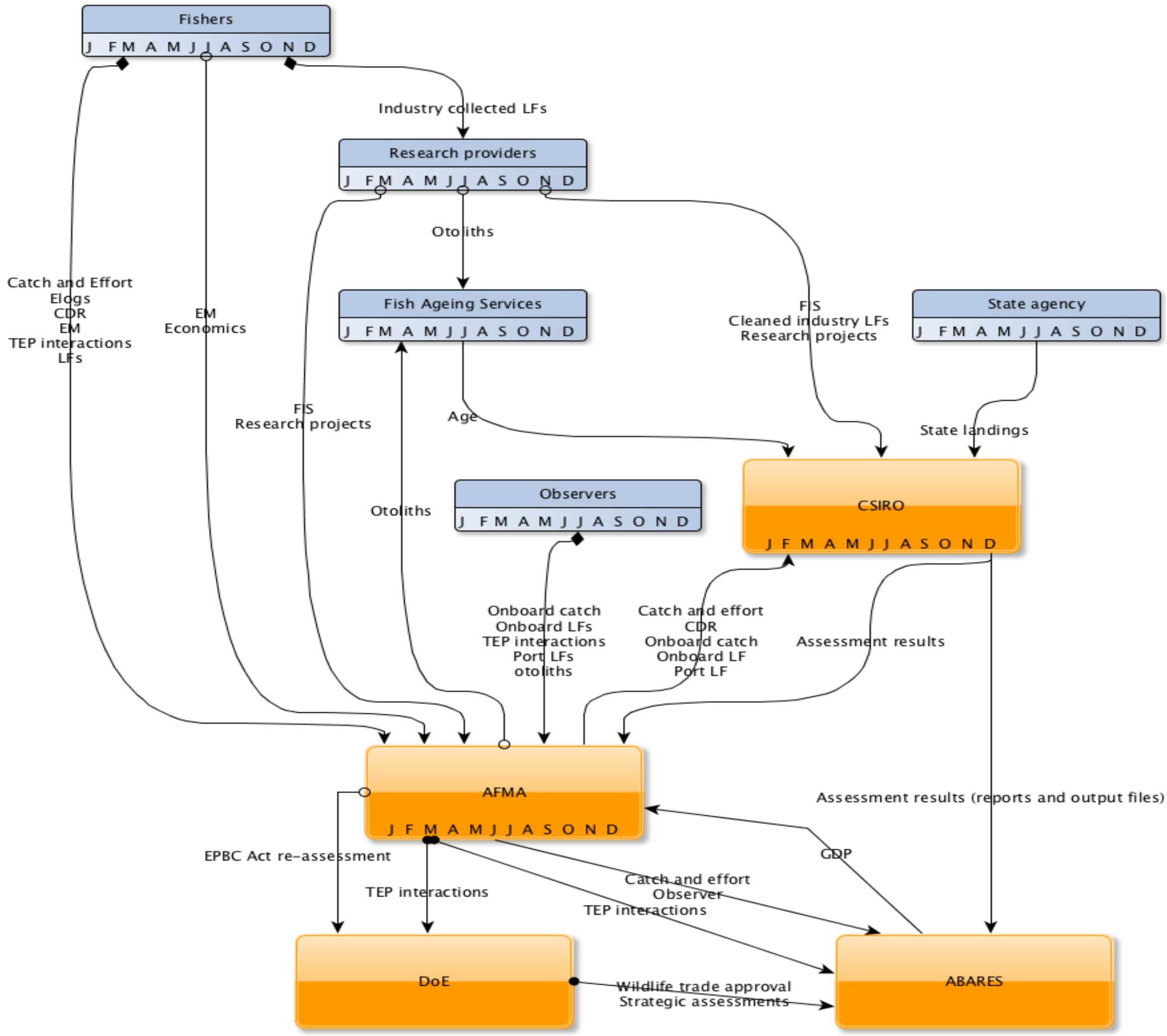


Figure 17. SESSF data collection and transfer. Symbols at each arrow's head indicate timing of data transfer: straight line = specific month; closed diamond = constantly or regular intervals; close circles = quarterly; open circles indicate "as required".

7.1.1. Daily fishing logbook / E-logs

Fishers record shot by shot data for each fishing operation in either paper or electronic logbooks (Table 13). Data recorded in logbooks include time and date, location, gear, effort and estimated catch weight by species. Fisheries managers can access the data through its Oracle database business intelligence interface (OBIEE) and AFMA's data section distributes these data to ABARES and to other researchers (including CSIRO who currently conduct most of the stock assessments) as inputs to stock assessments and data summaries to RAGs (Figure 18 and Figure 19). These data need to be cleaned and processed to before use in assessments.

TEP species interactions are reported on Listed Marine and Threatened Species Forms that are supplied with Daily Fishing Logbooks. All Commonwealth fisheries are accredited under Part 13 of the *EPBC* Act, which requires that any interactions must be reported to the Department of the Environment and Energy (DoEE). A Memorandum of Understanding (MOU) was established between AFMA and the DoE for fishers to report interactions to AFMA, and for AFMA to supply the DoE with quarterly summary reports. Additional data may be required for individual interaction reports if requested by DoE including location, time and date, presence of an observer, sex and life stage (Table 14).

Commonwealth waters of the SESSF adjoin the State waters of NSW, Victoria, Tasmania, South Australia and Western Australia. Commercial catch data for Commonwealth quota species taken in State fisheries are used in stock assessments and TAC calculations for some species. As part of the AFMA-funded ISMP data services project, CSIRO submits data requests to each State fisheries agency for total catch by species and calendar year (Figure 20).

Table 13. Daily fishing logbooks used by each sector of the SESSF.

Sector / sub-sector / gear	Logbook name
CTS	EFT01B - Eastern Finfish Trawl Daily Fishing Log
ECDTS	EFT01B - Eastern Finfish Trawl Daily Fishing Log
GABTS	SWT01A or SWTO1A - Southern and Western Finfish Trawl Daily Fishing Log
GHaTS / ScHS	LN01BA - Line Fishing Daily Fishing Log
GHaTS / SGSHS / Hook	LN01B - Line Fishing Daily Fishing Log
GHaTS / SGSHS / Gillnet	NT01B - GILLNET Fishing Daily Fishing Log
GHaTS / Trap	TR01 - Trap Fishing Daily Fishing Log

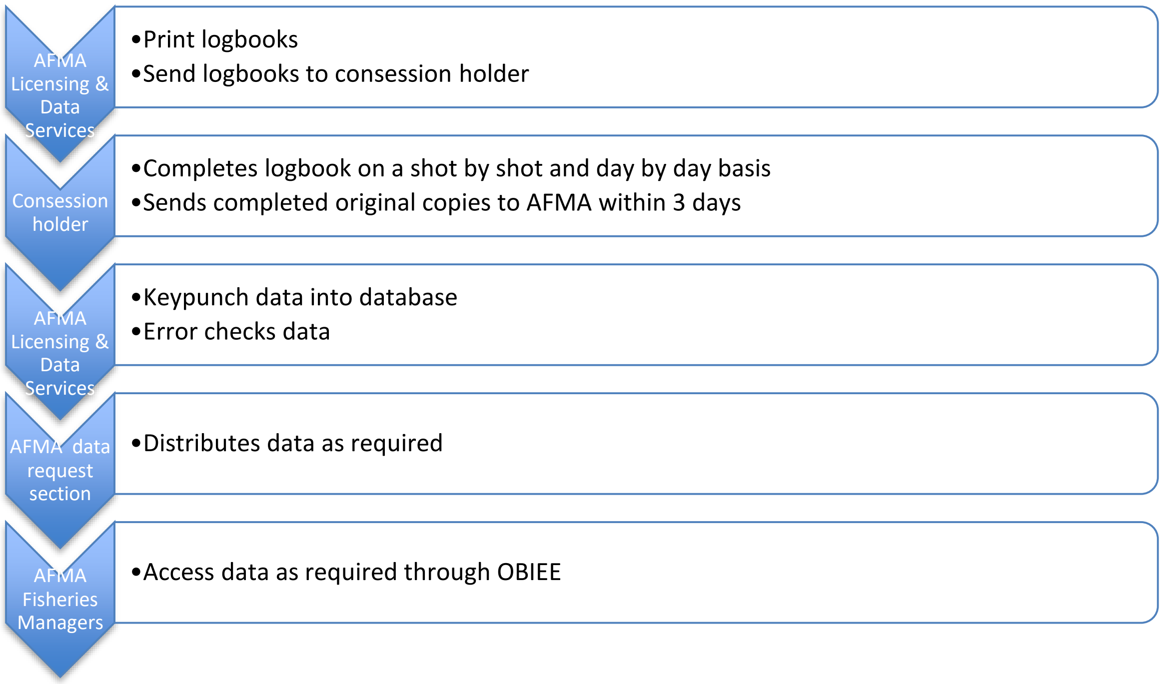


Figure 18. Process in the collection of daily fishing logbook data from paper logbooks.

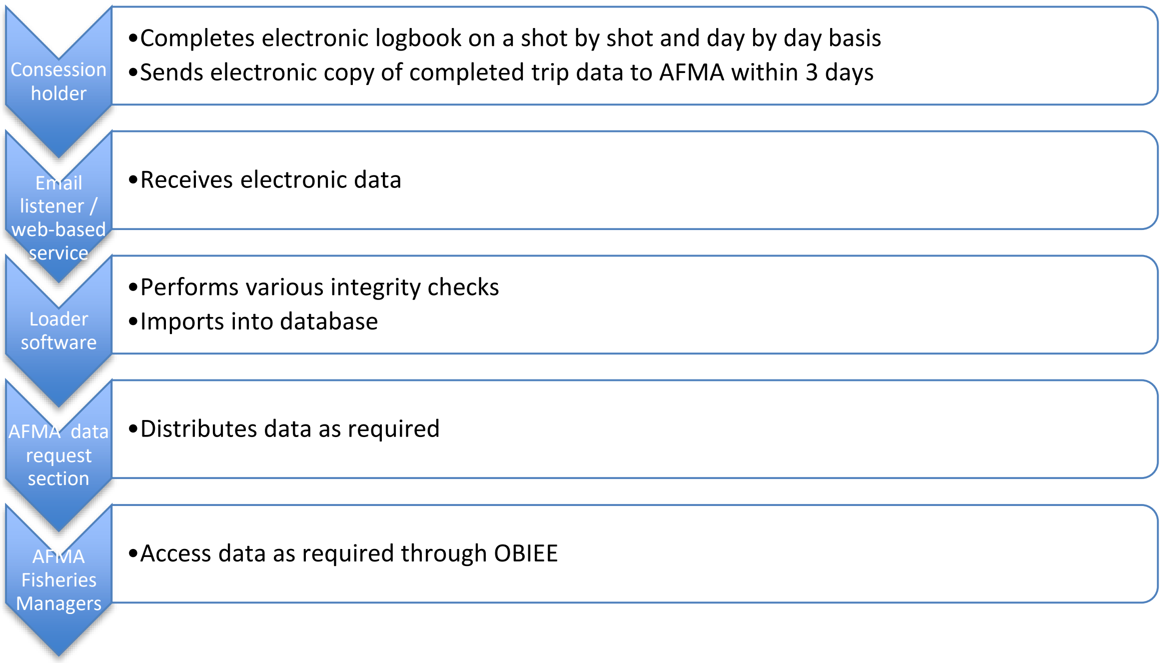


Figure 19. Process in the collection of daily fishing logbook data from electronic logbooks.

Table 14. Fields included on Listed Marine and Threatened Species Forms.

Boat name	Time at which interaction occurred
Distinguishing symbol	Latitude
Date of interaction	Longitude
Log No.	Interaction type
Corresponding logsheet no.	Band or tag number
Observer on board	Life status
Species name	Comments
Number of sea horses	

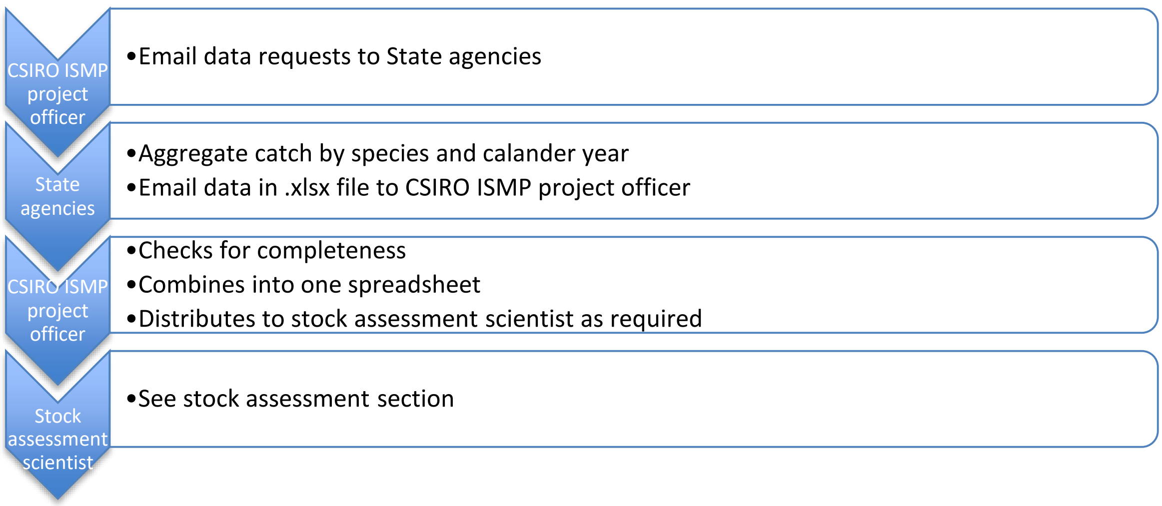


Figure 20. Process in the collection and processing of State catch data.

7.1.2. Catch disposal records

Catch disposal records are used to record accurate weights of each species landed, and are used by compliance officers to provide evidence of the source of fish consignments (Table 15). All SESSF concession holders are required to unload their retained catch to AFMA-licensed fish receivers, and both are required to complete the following:

- vessel and licence details, trip, unloading and overall catch information, as well as daily fishing log numbers so that the CDR data can be matched to daily fishing log data.
- accurate weight by species, form code and catch from State waters.
- details of the fish receiver and accurate weight of fish received by species.

Once in the database, fisheries managers can access the data through OBIEE (Figure 21). Catches reported in CDRs are used by AFMA to keep track of catches against statutory fishing rights and produce Catchwatch reports. AFMA's data section distributes these data to ABARES and other researchers (including CSIRO) as inputs to stock assessments and data summaries to RAGs.

Table 15. Catch disposal records used by each sector of the SESSF.

Sector / sub-sector / gear	Logbook name
CTS	SESS2A or SESSF2B - Commonwealth Catch Disposal Record
ECDTS	SESS2A or SESSF2B - Commonwealth Catch Disposal Record
GABTS	GAB2C - Great Australian Bight Trawl Fishery Catch Disposal Record
GHaTS / ScHS	SESS2A or SESSF2B - Commonwealth Catch Disposal Record
GHaTS / SGSHS / Hook	SESS2A or SESSF2B - Commonwealth Catch Disposal Record
GHaTS / SGSHS / Gillnet	SESS2A or SESSF2B - Commonwealth Catch Disposal Record
GHaTS / Trap	SESS2A or SESSF2B - Commonwealth Catch Disposal Record

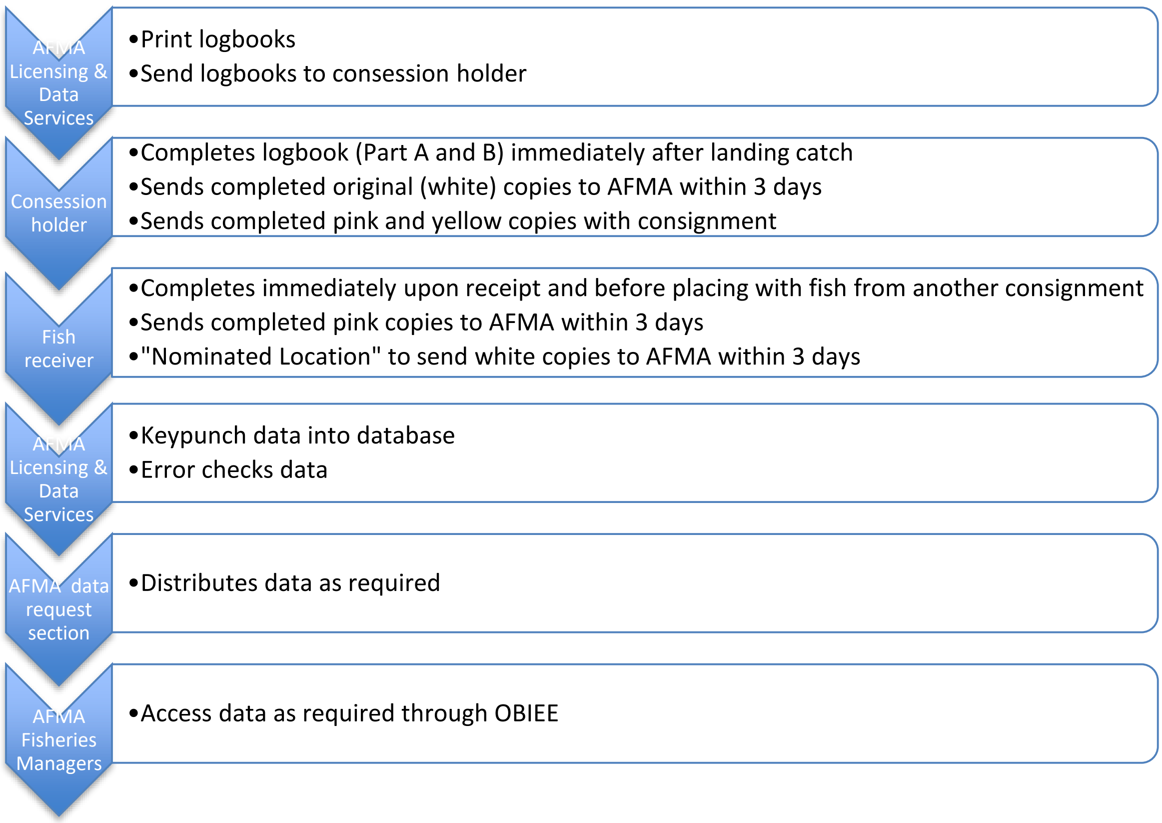


Figure 21. Process in the collection of catch disposal record data from paper logbooks.

7.1.3. Observer data

Since 1992, fisheries observer programs (the Integrated Scientific Monitoring Program – ISMP) have collected information on the age- and size-structure of the main target species to feed into stock assessments, as well as data on the species composition of retained and discarded catch and interactions and numbers of TEP species. At-sea observations take place during commercial fishing operations, with sampling effort designed to be distributed according to relative fishing effort (Figure 22). Observers also undertake port measuring for length frequencies and to collect otoliths from the main landed species.

Otoliths collected by observers are sent to the AFMA observer coordinator where the data are checked and keypunched before being sent to Fish Ageing Services (FAS) for processing (Figure 23).

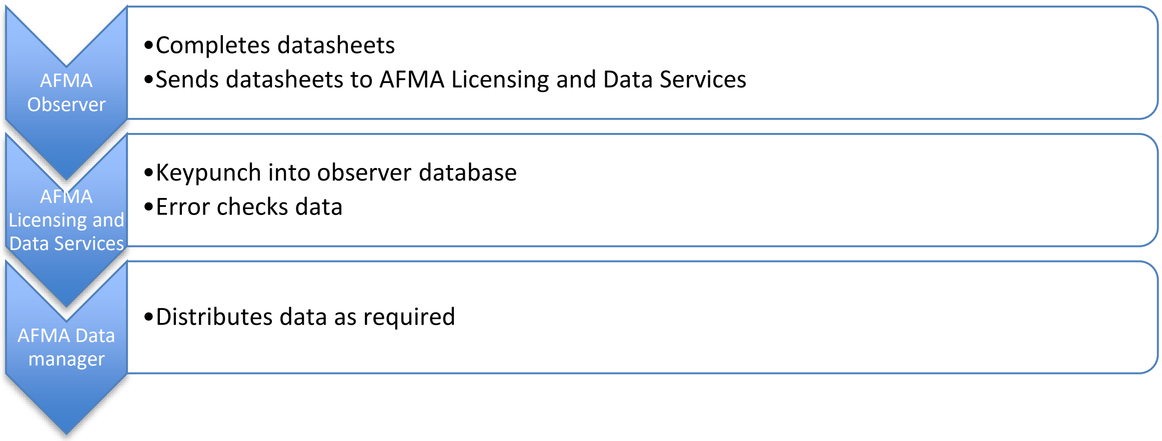


Figure 22. Process in the collection of onboard observer data.

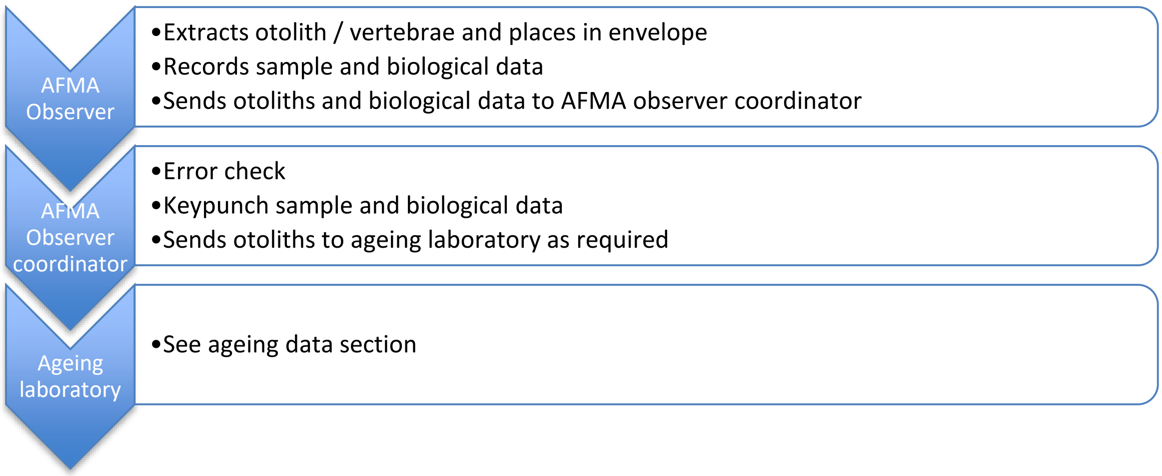


Figure 23. Process in the collection of otoliths from observer trips.

7.1.4. Fishery independent surveys

Acoustic optical system (AOS) surveys are periodically commissioned by Industry and undertaken by CSIRO to acoustically estimate biomass of spawning aggregations of Orange Roughy and of Blue Grenadier. Data are used to monitor stock rebuilding, and as input into stock assessments (Figure 24). The AOS operates in two modes. In 'Survey Mode' the system is operated at ~300 m from the target species to obtain acoustic volume backscatter data for the purpose of echo integration-based biomass estimation. In 'Trawl Mode' the system operates as per a standard demersal trawl. In this mode, close range acoustics are collected to establish fish target strength (TS). These measurements are complemented with video and stereo digital still-photo data which provide verification of species identification and their orientation to help provide reliable estimates of TS. Catches are also sampled for species composition, length, weight, and spawning stage.

Multi-species FIS trawl surveys are undertaken in the area of the CTS and GABTS using a model design and stratified random design respectively. Observers record information about the fishing operations, environmental observations, catch species composition, length frequency measurements and collect otolith samples (Figure 25). FIS data provide fishery-independent estimates of relative abundance with associated CV's. These abundance indices are recorded in project reports, and made available to CSIRO stock assessment scientists. Otoliths collected by the FISs are retained for age estimation in addition to ISMP data.

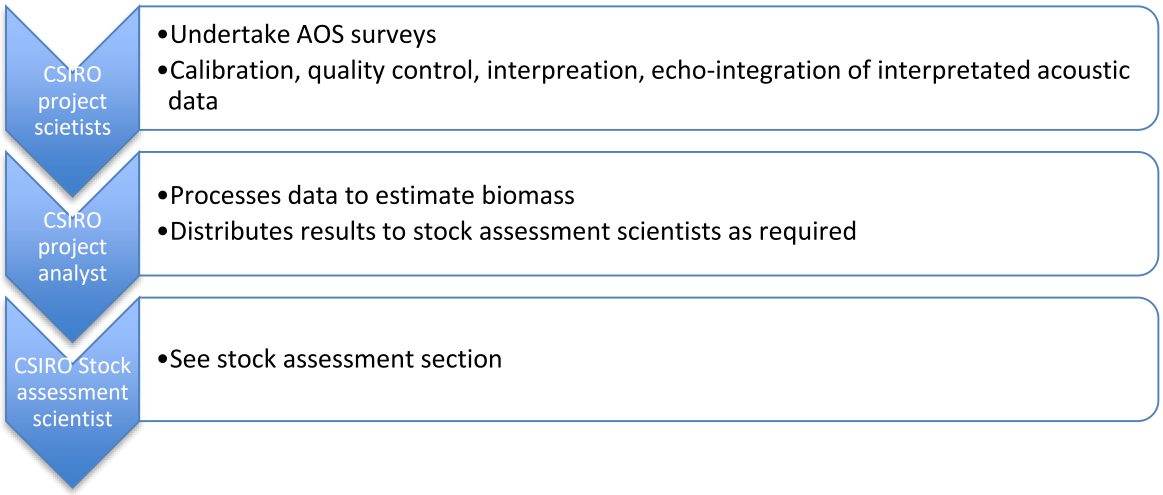


Figure 24. Process in the collection of AOS survey data.

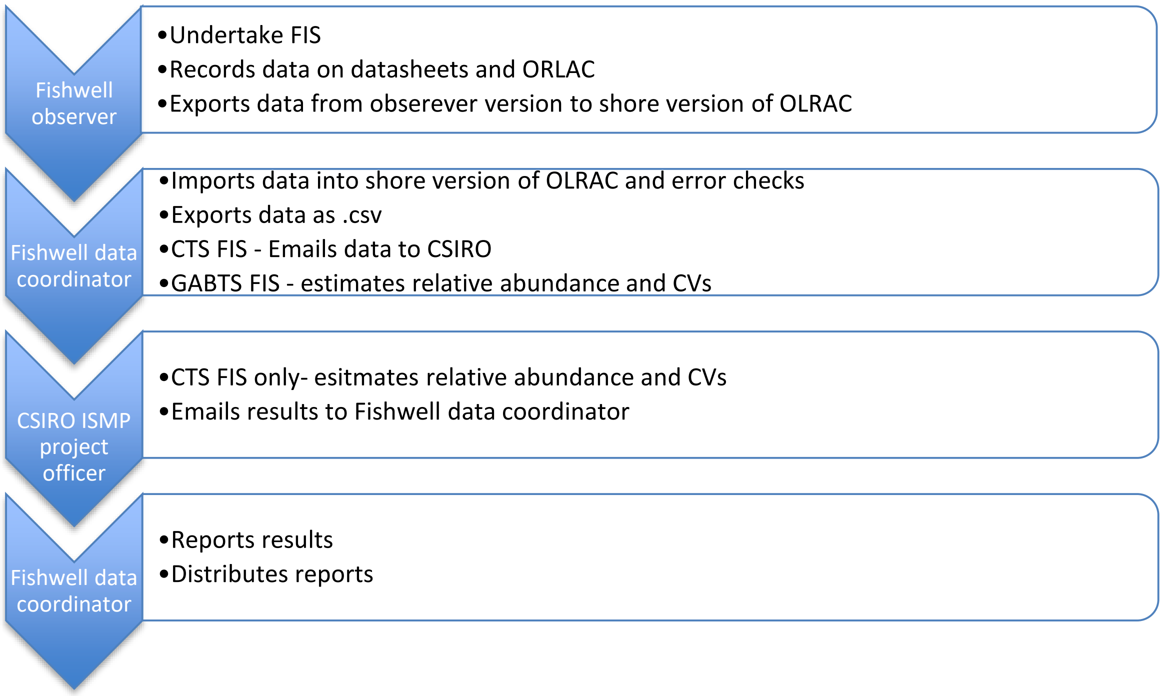


Figure 25. Process in the collection of FIS trawl data.

7.1.5. Ageing data

Otoliths and ancillary data collected by AFMA's observer program and the FIS are ultimately sent to Fish Ageing Services (FAS) as required to meet targets for assessments or other *ad hoc* purposes (Figure 26). Upon receipt, FAS keypunch batch registration details and biological data. If not required immediately, otoliths are stored. When processing, otoliths are weighed and zone counts are made using methods based on those described by Morrison *et al.* (1998), with number of zones, distance between zones, edge type and 'readability' all recorded. Ageing data are then sent to the CSIRO SESSF data manager during July of each year who makes the data available to stock assessment scientists.

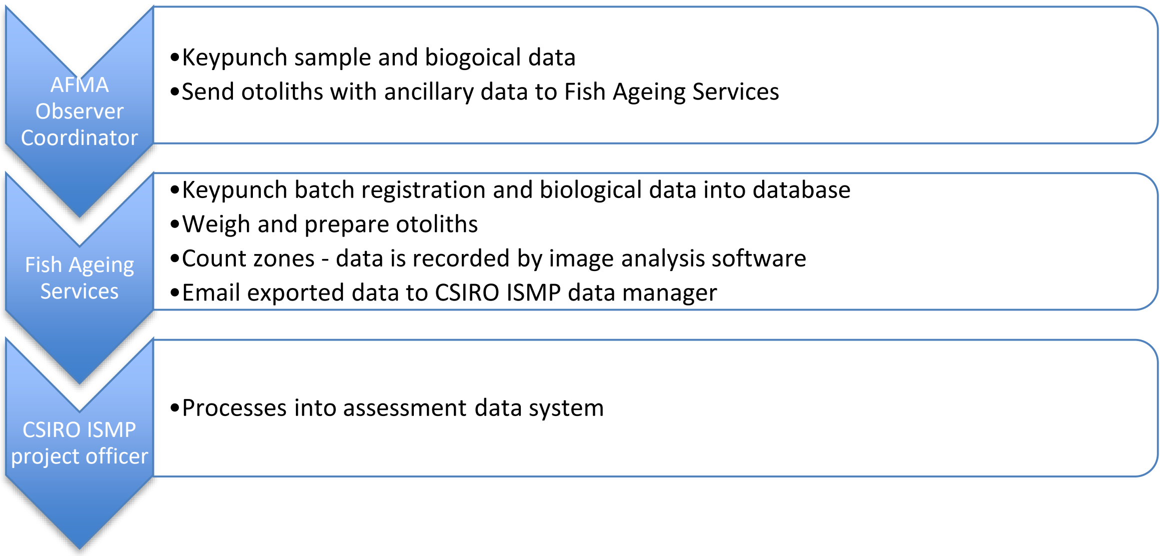


Figure 26. Process in the collection of ageing data.

7.1.6. Dedicated research projects

There is a variety of research projects undertaken in the SESSF that are carried out according to specific fishery data needs. It is outside the scope of this project to describe processes for every biological study conducted on SESSF species, but the typical process of an example stock structure study is shown in Figure 27. Examples of different types of research projects are provided below:

- Biological – Larval distribution of Blue Grenadier (*Macruronus novaezelandiae*) in south-eastern Australia: further evidence for a second spawning area (Bruce *et al.*, 2001).
- Stock structure – Use of otolith chemistry and shape to assess the stock structure of Blue Grenadier (*Macruronus novaezelandiae*) in the Commonwealth Trawl and Great Australian Bight fisheries (Hamer *et al.*, 2009).
- Biomass estimation – Close Kin Genetics as an abundance index for School Shark (Mark Bravington, CSIRO).
- Gear studies – Trials of longlines to target Gummy Shark in SESSF waters off South Australia (Knuckey *et al.*, 2014).
- Interaction studies – Mitigating seal interactions in the SRLF and the gillnet sector SESSF in South Australia (Goldsworthy *et al.*, 2010).
- Bycatch mitigation studies – Maximising yields and reducing discards in the South East Trawl Fishery through gear development and evaluation (Knuckey and Ashby, 2010).
- Survey of fishing gears (AFMA, 2013d)

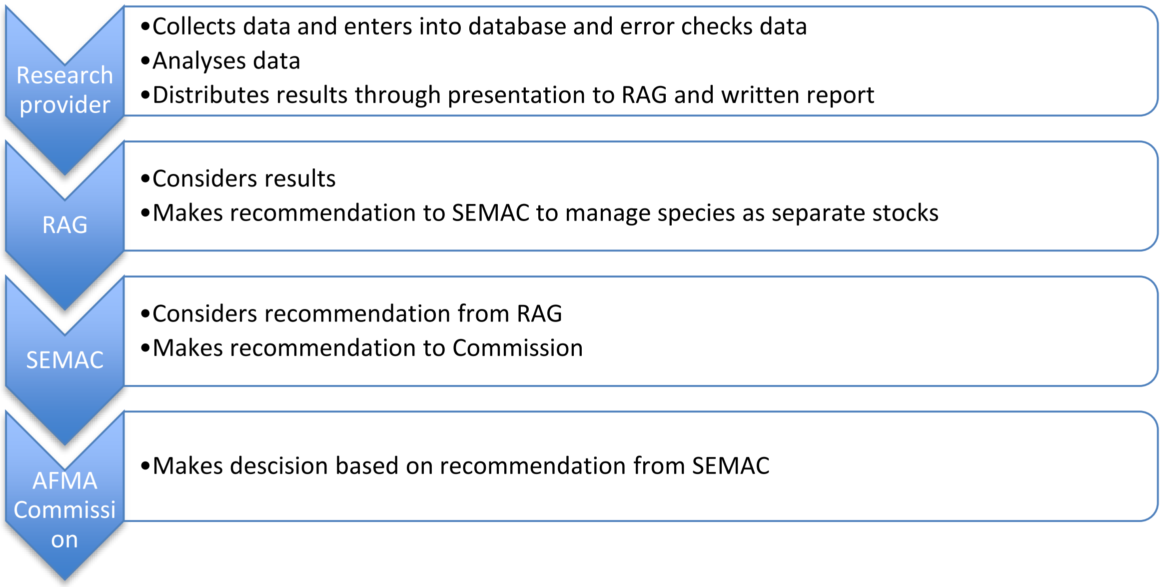


Figure 27. Process in the collection of hypothetical stock structure study.

7.1.7. Industry-collected length frequency data

There are two programs for collection of fish length frequency data by the fishing industry. The longest running and most successful is in the GABTS, where fishers have been recording length measurements of Bight Redfish and Deepwater Flathead since 2007. As detailed in the Boat Operating Procedures Manual (GABIA, 2010), fishers are required to measure one to two bins of ungraded Bight Redfish and Deepwater Flathead from each shot using standardised methods, and to record lengths on provided datasheets. Datasheets are then sent to AFMA where they are keypunched (Figure 28). Industry also implemented a specific project focusing on collecting lengths of Blue Warehou in the CTS when this species was determined to have declined, with data collection and processes similar to that of the GABTS. These data have not been collected for a number of years.

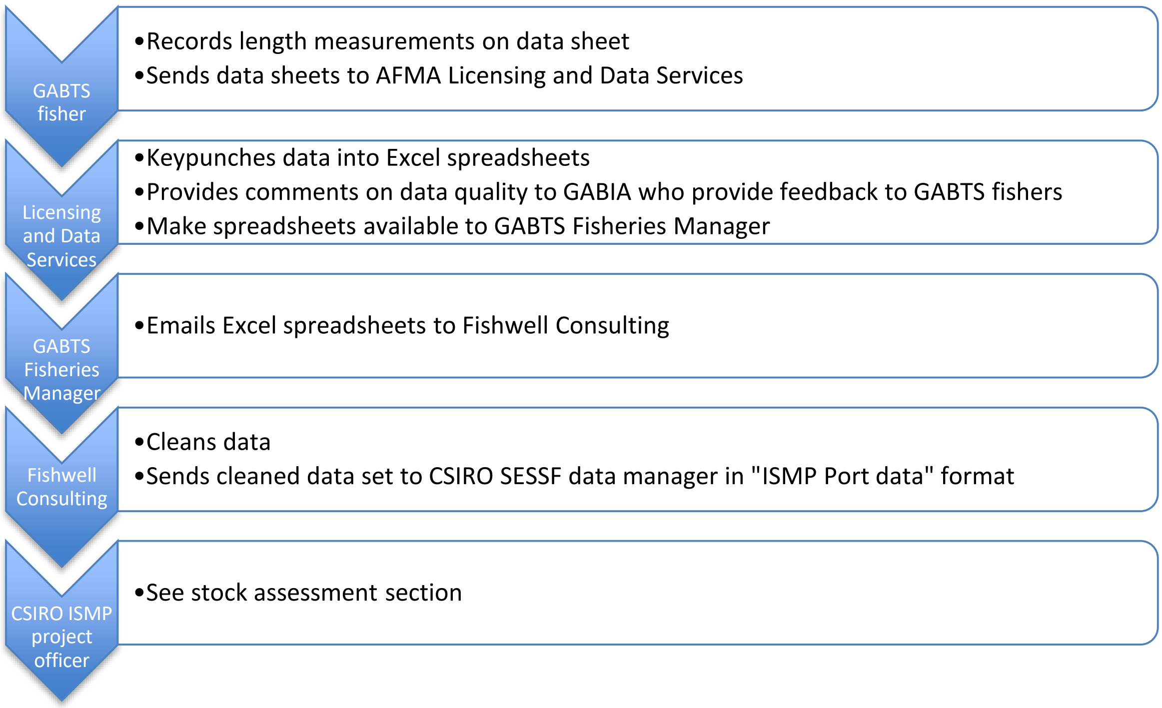


Figure 28. Process in the collection of Industry collected length frequency data.

7.1.8. Electronic monitoring systems

Fishery management agencies are increasingly using Electronic Monitoring Systems (EMS) as cost effective methods of on-board data collection for compliance and research. The two main EMS systems used in the SESSF are sensor-activated video cameras and Vessel Monitoring Systems (VMS).

All vessels operating in Commonwealth managed fisheries are fitted with a VMS to monitor position, course and speed. Data are sent to AFMA at set intervals via Inmarsat-C and other communications satellites to a land station, and then on to an AFMA database via a secure internet connection (Figure 29). VMS data are used mainly for compliance, but can be used for research, for example, to improve the quality of location data (Harrington *et al.*, 2007). Near real-time data are observed by AFMA's E-Monitoring Manager through a GIS workspace, and data can be accessed by Fisheries Managers through OBIEE and the Fleet Information System.

The EMS that AFMA uses in the SESSF includes video cameras and other sensors that record video footage time and location of fishing activity, operational data and system diagnostics, and performance (e.g. power outages etc.). Data are collected at 10 second intervals and, with the exception of video, data are transmitted to AFMA and the third party e-monitoring service provider for near real-time monitoring (Figure 30). Video cameras can be positioned at locations to capture imagery of different fishing activities (e.g. setting and hauling), and are activated by hydraulic and rotation sensors attached to fishing equipment such as the net drum. Once activated, imagery is captured onto removable hard drives by the system's control centre, together with time, date and location. Hard drives are swapped on a monthly basis, with the concession holder being responsible for exchanging hard drives and sending these in secure, pre-paid satchels to AFMA. Once AFMA receives the drives they are copied and stored securely. Depending on the level of cover required, a proportion of hard drives are sent to an independent data analyst for extraction of gear and effort, catch composition, wildlife interactions and / or discarding data. AFMA can then compare these data with data from daily fishing logbooks and catch disposal records for quality assurance purposes.

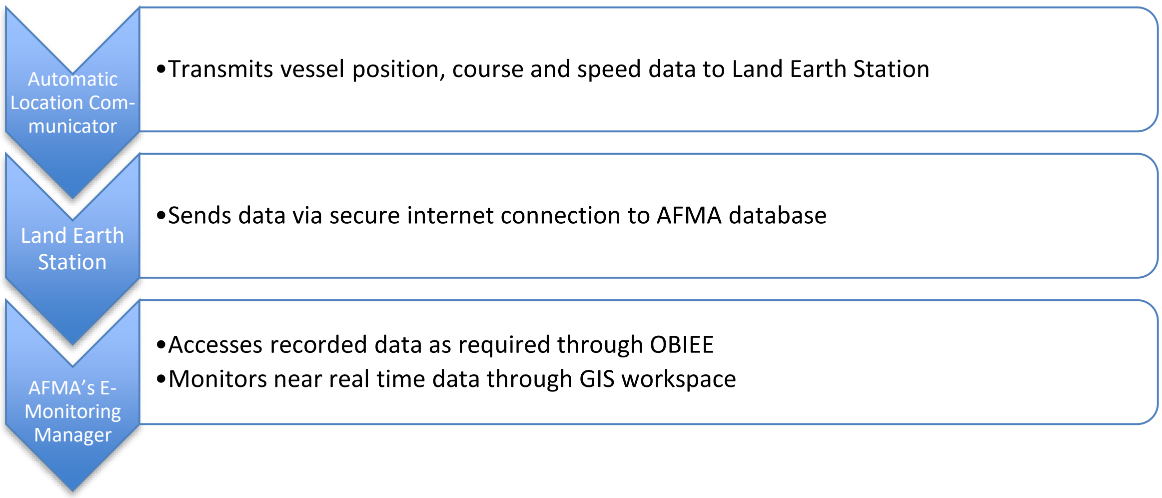


Figure 29. Process in the collection of VMS data.

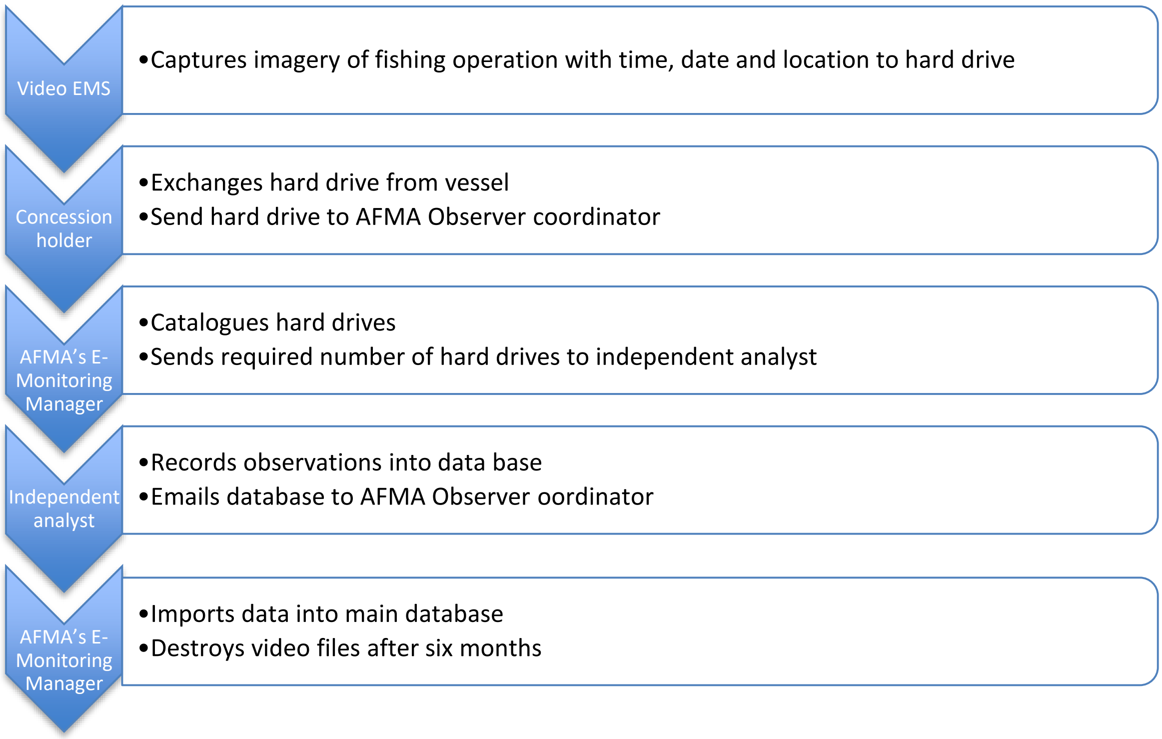


Figure 30. Process in the collection of EMS footage data.

7.1.9. Owner / vessel registry

AFMA maintains a registry of Boat Nominations, Statutory Fishing Rights, and Fishing Permits. To nominate a boat, Boat Nomination and Attachment BN-SESS forms must be completed and sent to AFMA.

7.2. Assessment tools

7.2.1. Single species assessments

Tiered assessment approaches have been developed and applied to stocks in the SESSF for many years to apply suitable assessment methods from data rich to data poor stocks (Smith *et al.*, 2008; Little *et al.,* 2011). They were recently expanded to cater for lower information stocks, such as where only catch data are available (Dichmont *et al.,* 2013). Haddon *et al.* (2014) states "The use of a tiered system of assessment methods and associated control rules allows for the development of detailed, integrated stock assessments (Tier 0 and 1) down to the lowest Tiers where data are limited to catch rates, catches, or even just catches (Tiers 6 and 7). Below these tiers is the Ecological Risk Assessment, which aims to determine whether there are particular species that are exceptionally vulnerable to the effects of fishing".

Preparation of various data from the sources is undertaken using a routine process (Figure 31). The types of data that are collected and the form of assessment undertaken to feed into the harvest control rule for each tier are outlined in Table 16. Although the harvest control rules can vary widely for a given tier, they are designed to meet the requirements of the HSP for target species — to achieve the target maximum economic yield (MEY) while avoiding biologically defined limits (limit reference points or LRPs) with a probability that is defined in the HSP (Haddon *et al.,* 2014).

Table 16. Tier number and description of minimum data requirements (from Dichmont *et al.,* 2013, and Haddon *et al.*, 2014).

Tier	Tier Description	Minimum data requirements
0	Robust assessment of *F* and *B* based on fishery dependent AND independent data Time series of independent surveys and verified catch, effort and/or catch rate data.	Data required to standardise catch rates (if used).
1	Robust assessment of *F* and *B* based on fishery dependent data ONLY Time series of verified catch, effort and/or catch rate data.	Data required to standardise catch rates (if used).
2	Assessment of *F* and *B* based on fishery dependent and/or fishery independent data	Time series of catch, effort and/or catch rate data.
3	Empirical estimates of *F* based on size and/or age data	Time series of catch only. Representative sample of size and, if relevant, age
4	Empirical estimates of: • relative biomass based on fishery dependent data • within season changes to relative biomass based on fishery dependent data • relative biomass based on fishery independent surveys	Time series of catch only or time series of fishery dependent data such as catch rates or independent survey data.
5	Empirical estimates of *F* based on spatial distribution of effort relative to species distribution	Patchy catch and effort data or distribution of catch/effort relative to the species distribution
6	No estimate of biomass and *F*; use of fishery-dependent species-specific triggers	Patchy catch and/or effort data by species
7	No estimate of biomass and *F*; use of fishery-dependent triggers for groups of species	Patchy catch and/or effort data by groups of species

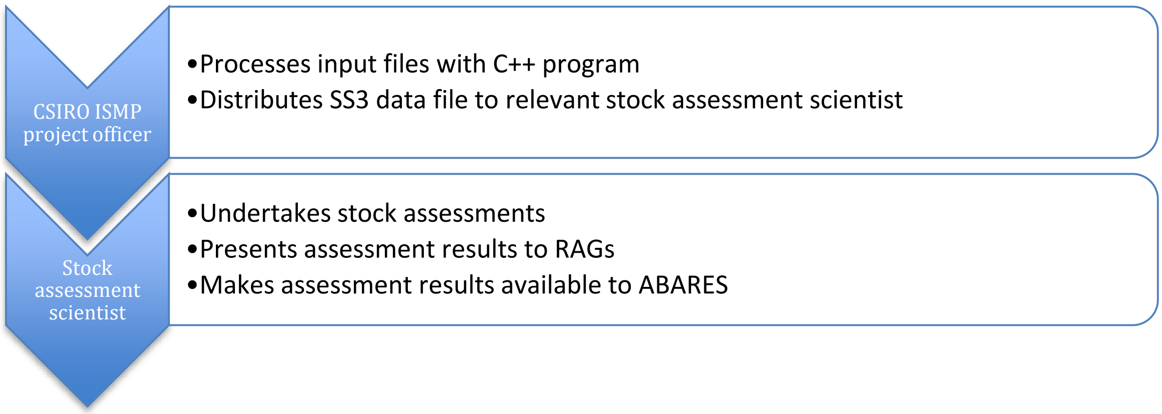


Figure 31. Process in the processing of stock assessment data.

7.2.2. Ecological risk assessment

Ecological Risk Assessment for Effects of Fishing (ERAEF, Hobday *et al.*, 2007) underpins AFMAs Ecological Risk Management Framework (ERMF). It was developed by CSIRO and AFMA to assess and monitor the risks presented by Commonwealth fisheries to the ongoing sustainability of species populations (stocks), habitats, and communities. AFMA uses ERA results to inform its ecological risk management responses which in turn are designed to assist AFMA in meeting its related legislative, corporate, and policy objectives, including to gain accreditation for its fisheries under Part 13 of the *EPBC* Act, and to assist its fisheries to gain accreditation against other standards / processes (e.g. MSC).

The original ERA methodology (Hobday *et al.*, 2007 and Hobday *et al.*, 2011a) was revised in 2016-17 but still retains a three level hierarchical approach to assessing risk across each of the five ecological components, by applying the following sequential phases (Figure 32):

Scoping: this phase identifies the fishery context, ecological sustainability objectives and hazards (fishery activities that may impact the ecosystem).

Level 1 - A comprehensive but largely qualitative Scale-Intensity-Consequences Analysis (SICA) of risk in which the most vulnerable “unit” (individual species) in each component (e.g. group of species) is assessed. This phase serves to exclude clearly “low risk” components (e.g. species groups) from analysis at level 2.

Level 2 - A more focused and semi-quantitative Productivity-Susceptibility Analysis (PSA) approach which assesses fishery risks to each unit (e.g. species) carried forward from Level 1. Units assessed to be at high risk at Level 2 can either be managed directly or carried forward to Level 3 for fully quantitative assessment.

Level 3 - A highly focused and quantitative “model-based” approach that accounts for spatial and temporal dynamics of units and fisheries and quantifies uncertainties around stock status.

AFMA (2017b) states that, following the development of the original ERAEF and the progression of species component ERA assessments to Level 2 across Commonwealth fisheries, two further developments occurred that improved the species-specific assessments of risk. The first was the development and application of Residual Risk Analysis (RRA) for the PSA, in recognition that the PSA methodology was unable to account for some management arrangements that mitigate risk, while the second was the development of a quantitative rapid risk assessment tool for basic Sustainability Assessment for Fishing Effects ‘b-SAFE’, which was applied to high risk species following PSA for some species groups and was often referred to as Level “2.5”. A spatially-structured version of this (extended-Safe or e-SAFE) was subsequently developed.

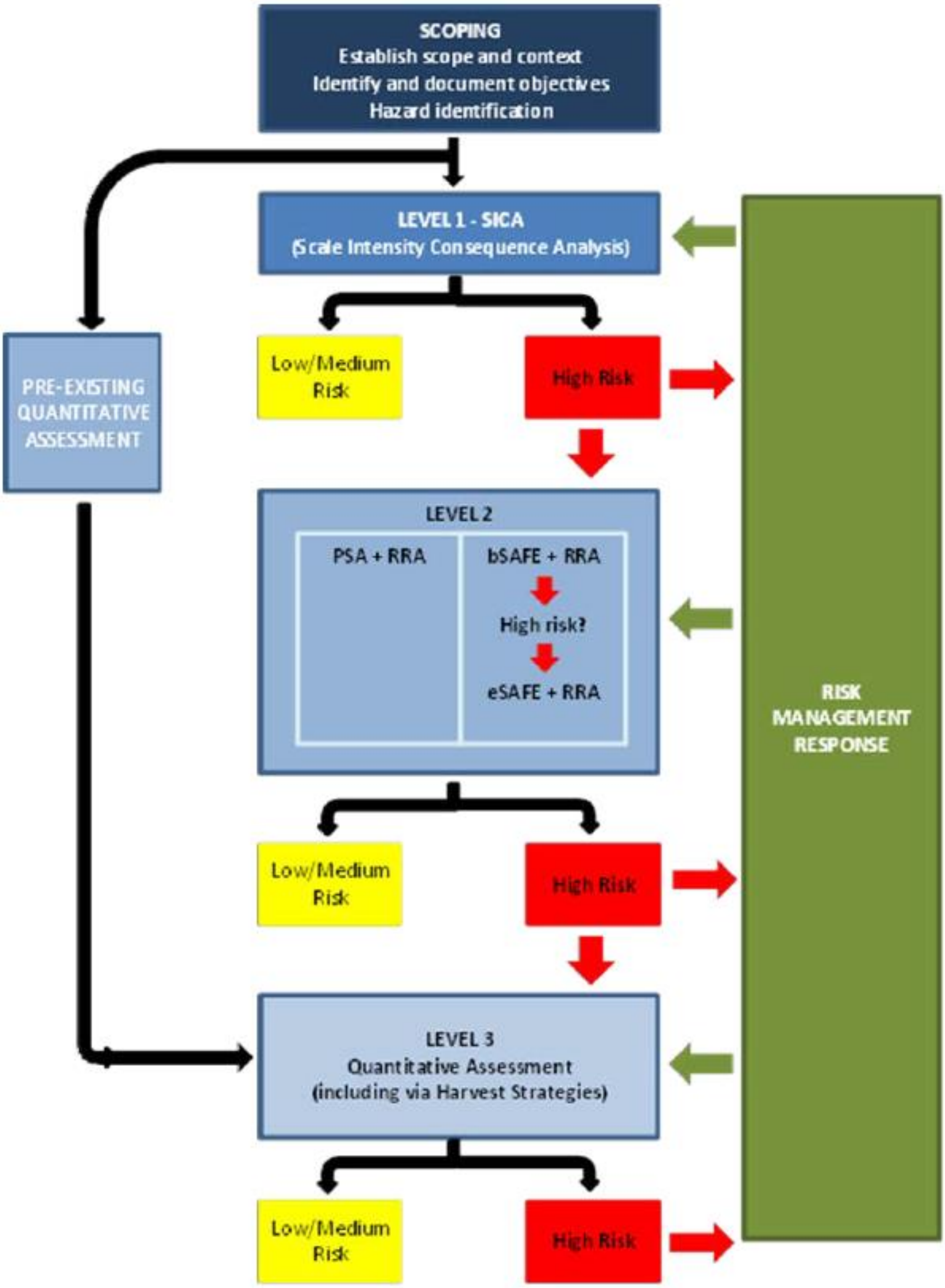


Figure 32. Schematic diagram of revised ERA approach with the 3 level hierarchical ERAEF methodology. SICA – Scale Intensity Consequence Analysis; PSA – Productivity Susceptibility Analysis; SAFE – Sustainability Assessment for Fishing Effects; RRA – Residual Risk Analysis. T1 – Tier 1. eSAFE may be used for species classified as high risk by bSAFE.

7.3. SESSF alternative assessment scenario evaluation

The SESSF is managed under the SESSF Harvest Strategy Framework in line with the HSP, introduced at the start of 2007. This framework consists of a number of harvest strategies designed to achieve a sustainable harvest with optimal economic returns from the main species in this fishery. Under these strategies, TACs are in place for 34 quota species, with catch trigger limits applied to two non-quota species. Ecological risk assessments are conducted to ensure byproduct, bycatch and TEP species are not unduly impacted. Additional spatial management and gear controls are used to reduce impacts on vulnerable bycatch species such as gulper sharks, seabirds, and marine mammals.

The 2012 Review of Commonwealth Fisheries: Legislation, Policy and Management review (Borthwick Review), and contemporaneous reviews of the HSP and the Commonwealth Policy on Fisheries Bycatch signalled potentially significant changes to fisheries management which will flow on to the monitoring and assessment arrangements. The outcomes of the HSP review indicate the need for revisions to elements of that policy to ensure that Australian fisheries, including the SESSF, continue to be viewed, locally and internationally, as sustainably and responsibly managed.

While there is a need to ensure and demonstrate the sustainability of the SESSF, there has been a long-term decline in the GVP and NER from the SESSF. In the 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 decrease has been largely attributed to reductions in catches of Orange Roughy, Blue Grenadier and Silver Warehou, under-catching of other TACs, generally lower fish prices, and has occurred despite increases in the prices of Tiger Flathead and Blue Grenadier. Net economic return in the CTS was negative until the structural adjustment in 2005–06, rose to a peak of $7.3 million in 2010–11, decreased 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 GHaTS, 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 falls 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).

In this financially challenging environment, the overall purpose of the current project was to review the monitoring and assessment requirements required to meet the objectives of the fisheries management (including the revised HSP and Fisheries Bycatch Policy), and to identify and evaluate the most cost-effective monitoring and assessment options to meet these needs.

7.3.1. Monitoring and assessment

When the current project was initially proposed, a considerably larger budget was sought to enable thorough reconsideration and management strategy evaluation (MSE) testing of the monitoring and assessment options available for a complex, multi-species, multi-sector fishery. However, economic constraints did not allow a comprehensive simulation-based evaluation. Instead, the project focused on options for optimising efficiency and cost effectiveness using various combinations of the current monitoring and assessment tools.

The level and type of monitoring and assessment in the SESSF has been continually evolving. Limited shot-by-shot catch and effort data are available from 1918 (Klaer, 2001), but the spatial and temporal extent and precision of the data has altered many times since. The current catch and effort logbook system was introduced in late 1985 and, from 1986 on, there has been a continual improvement in the quality and amount of data available for assessment. Catch Disposal Records's were introduced with the advent of quota management in 1992 and independent scientific observer programs began around the same time. The focus of the monitoring has also changed over time, initially concentrating solely on the target species. Monitoring broadened during the 1990s to include byproduct and bycatch species and, over the last decade, there has been a greater focus on fishery interactions with TEP interactions and impact on habitats and communities.

The monitoring and assessment that currently takes place in the fishery is largely driven by the overarching fisheries and environmental laws, regulations, and policies (Table 17). All of the legislation and policy documents of relevance to the SESSF were reviewed to provide a description of their objectives, monitoring and assessment requirements, and their use of this information.

Critically important for the current project are the HSP and the Bycatch Policy, including recent reviews and associated implications for monitoring and assessment. There are more than 600 species caught in or interacting with the SESSF, of which only about a hundred have some commercial value and are landed. Of those that are landed, about 30 species make up 93% of the value of the catch. Historically, the HSP related to only "key commercial species" — effectively the quota species (see Appendix 6) — and these required some level of quantitative (Tier 1 – Tier 4) assessment to measure the stock against an MEY target and a limit reference point. All other (non-TEP) species implicitly fell under the Fisheries Bycatch Policy and were assessed using an ecological risk assessment, but not actively managed under the HSP. Recent reviews of these policies have determined that all species with commercial value should fall under a revised HSP (Department of Agriculture and Water Resources (DAWR); Figure 33). A key principle underpinning the reviews was that all species caught or affected by fishing operations are managed under one or other of the policies. Accordingly, many previously unmanaged minor byproduct species will now reside under the HSP. All stocks will need to be managed appropriately for the category in which they fall, within economic, capability and data availability constraints.

Although these policies and regulations set the framework for fisheries reporting, the actual frequency, specifications and extent of the monitoring and assessment required to underpin this reporting are determined by AFMA through SERAG, GABRAG, SESSRAG, SEMAC and GABMAC. Key policy documents prescribing some of these requirements are listed in Table 17 below and described in Appendix 5: SESSF legislation and policy documents.

Table 17. SESSF legislation and policy documents.

- *Fisheries Management* Act 1991 No. 162, 1991 as amended
- *Fisheries Administration* Act 1991
- Southern and Eastern Scalefish and Shark Fishery Management Plan 2003
- EPBC Act 1999
- Review of Commonwealth Fisheries: Legislation, Policy and Management
- Guidelines for Implementation of the Commonwealth Fisheries Harvest Strategy Policy
- Final report on the review of the Commonwealth Fisheries Harvest Strategy Policy and Guidelines
- Harvest Strategy Framework for the Southern and Eastern Scalefish and Shark Fishery
- National Policy on Fisheries Bycatch
- Report on the review of the Commonwealth Policy on Fisheries Bycatch, Department of Agriculture, Fisheries and Forestry, Canberra.
- AFMA's Program for Addressing Bycatch and Discarding in Commonwealth Fisheries: an Implementation Strategy
- Threat Abatement Plan 2014 for the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations
- Blue Warehou (*Seriolella brama*) Stock Rebuilding Strategy 2008 (Revised April 2012) and draft Blue Warehou (*Seriolella brama*) Stock Rebuilding Strategy Revised 2014
- Commonwealth Trawl Sector (Otter Board Trawl & Danish Seine) Bycatch and Discarding Workplan
- Great Australian Bight Trawl Fishery Bycatch And Discarding Workplan
- Automatic Longline Fishery Bycatch And Discarding Workplan
- Shark Gillnet Fishery Bycatch And Discarding Workplan
- MOU Between the Australian Fisheries Management Authority and the Department of the Environment and Heritage for the Reporting of Fisheries Interactions with Protected Species Under the *Environment Protection and Biodiversity Conservation* Act 1999
- Orange Roughy Conservation Program
- School Shark Stock Rebuilding Strategy 2008
- Eastern Gemfish Stock Rebuilding Strategy 2008 and draft Eastern Gemfish (*Rexea solandri*) Stock Rebuilding Strategy Revised 2014
- Australian Sea Lion Management Strategy
- Dolphin Strategy: Minimising Gillnet Bycatch
- Upper-Slope Dogfish Management Strategy

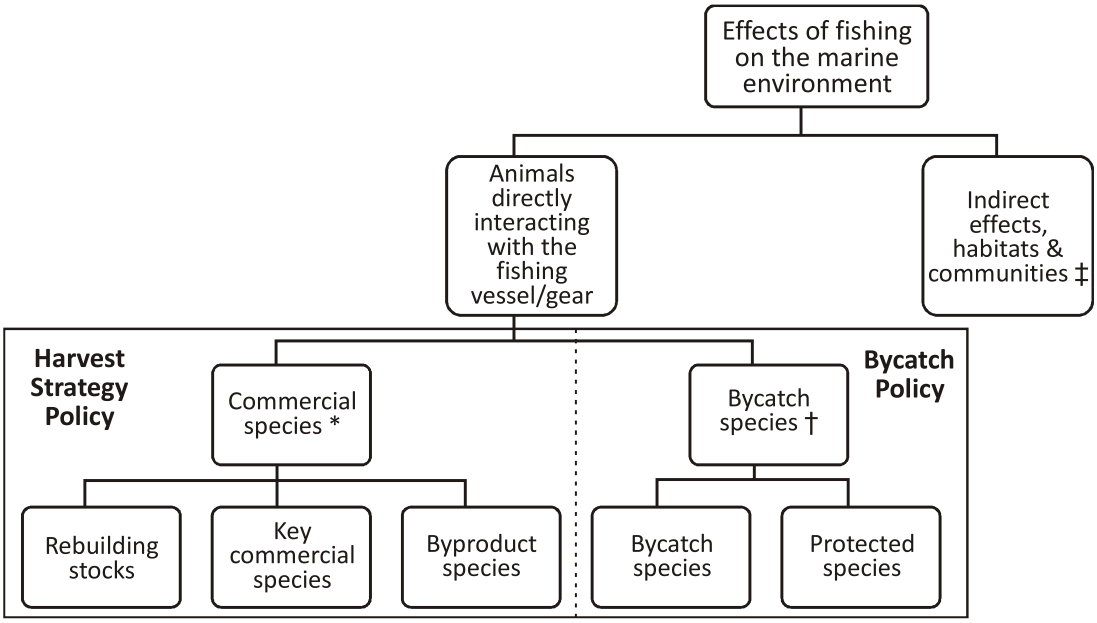


Figure 33. Proposed species classifications under a revised HSP and Bycatch Policy. Key commercial species include both Primary and Secondary species.

‡To be covered by future underpinning policy on the ecosystem approach to fisheries management.
* Includes key commercial species under rebuilding strategies and species sought by recreational fishers that are also kept by commercial fishers'.
†Includes species sought by recreational anglers and not retained or prohibited from being retained by commercial fishers.

7.3.2. Evaluation of alternative assessment scenarios

In response to expectations concerning species categorisation under the revised Commonwealth Harvest Strategy and Bycatch Policies, all species encountered in the SESSF were classified into Primary, Secondary, Byproduct and Bycatch species. A number of alternative scenarios were then explored, applying different assessment methods to different species categories or species, and varying the frequency with which certain data collection components, data analysis components, fisheries independent surveys, or stock assessments are conducted.

These analyses were conducted using an MS Excel ® spreadsheet containing recent data on catch, price and GVP for all of the species encountered in the SESSF. This spreadsheet allows for flexible specification of scenarios, with any of the settings able to be varied to specify and explore any combination of alternative species classifications, assessment methods, and assessment frequencies. The results presented below were all derived using this spreadsheet.

7.3.2.1. Species classification

For all scenarios, the species classification used a rule-based classification, with species being allocated to a management category depending on their respective contributions to GVP and catch. Annual catch data were available for the years 2007 to 2014 from the AFMA databases, and the scenarios explored used recent average annual catches over the period 2012-2014. First-sale prices per species were obtained from ABARES for the seasons 2010-11 to 2014-15 and the average seasonal price over the period 2010-2015 was used to generate annual GVP and % GVP contributions for each species using the 2012-14 average annual catches.

The cut-offs for each category were selectable and a range of alternative cut-off values were explored by the project team to determine the most appropriate values to use to reflect relative species contributions to the SESSF. The chosen cut-offs in Table 18 resulted in what was considered to be the most appropriate species categorisation for use in scenario exploration across all sectors of the SESSF. Percent GVP was the primary measure to distinguish between Primary and Secondary species, and average annual catch was primarily used to distinguish between remaining categories. This resulted in the numbers of species per category shown in Table 18. The cumulative contribution of these species to annual fishery GVP is shown in Figure 34. The detailed categorisation of all species is shown in Appendix 6: Proposed classification and assessment of SESSF species.

Table 18. Percentage GVP and average catch cut-off values used to allocate species encountered in the SESSF to the four management categories.

Category	GVP %	Catch kg	No. Species
Primary	1.7%	500,000	11
Secondary	0.5%	110,000	20
Byproduct	0.1%	1,000	79
Bycatch	Remainder	Remainder	560
Total			670

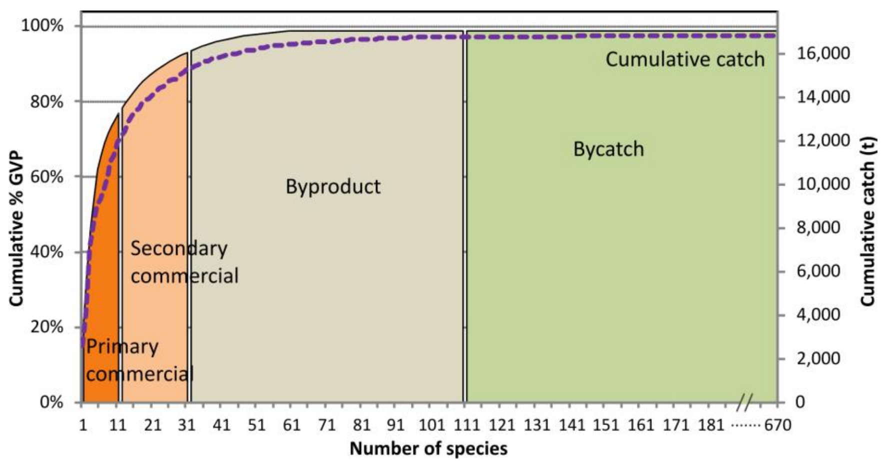


Figure 34. Cumulative % of GVP (shaded areas) and cumulative catch (dashed blue line) by species categorised as Primary (≥1.7% GVP or ≥500t catch), Secondary (0.5% to < 1.7% GVP, 110t to <500t catch), Byproduct (0.1% to <0.5% GVP, 1t to <110t catch) and Bycatch.

This categorisation was not changed between the alternative assessment scenarios explored, so the relative contributions of species categories to GVP and catch also did not change between scenarios. Alternative categorisation cutoff values may easily be explored and the assessment type for individual species can be manually changed on the Excel spreadsheet. It is expected that the South East Resource Assessment Group may need to reconsider and revise species classifications as species abundance, availability, market preferences and catch composition change over time.

7.3.2.2. Monitoring and assessment costs and cost allocation

In order to evaluate the potential costs of alternative assessment scenarios, recent costs of the various assessment types, data collection, and data analysis components were estimated and supplied by AFMA and by CSIRO. Assessment costs at each assessment tier were divided between individual assessment depending on number of assessments at each tier level. Annual 'fixed' data collection and processing costs were allocated to the assessment tiers as shown in Table 19 (indicated by 'y'). This allocation was selectable, but was not changed between the scenarios explored. Individual component costs were also unchanged for all but two scenarios (under which AFMA would assume a proportion of certain data preparation costs).

Table 19. Estimated data collection, data analysis and survey costs per component; allocation of these costs between the alternative assessment tiers (indicated by 'y'); and default (initial planned) frequency (years) for expenditure of each cost component. Underlined ISMP costs were doubled to explore doubled observer coverage.

	Assessment Tier							
Component	**1**	**3**	**4**	**5**	**ERA**	**Cost**	**Default Frequency**	**AFMA Data Preparation**
Logbooks	y	y	y	y		$200,000	1	
CDRs	y	y	y	y		$20,000	1	
ISMP Port	y	y				$50,000	1	
ISMP Onboard	y	y	y	y	y	$350,000	1	
E-monitoring						$643,000	1	
Data Services	y	y	y	y	y	$180,000	1	**$87,000**
Ageing *	y	y				$262,000	1	
Staff	y	y	y	y		$45,000	1	**$55,000**
Data Methods *	y	y	y	y		$80,000	1	
Meeting days	y	y	y	y		$249,000	1	**$209,000**
Standardisation *	y		y			$64,615	1	**$13,000**
FIS Survey Cost						$645,000	1	
Orange Roughy Survey Cost						$355,000	3	

* Data preparation components for which scheduling frequency was changed under alternative scenarios.

ISMP observer costs were doubled for one scenario, to explore the effect on overall costs of a hypothetical doubling of observer coverage, to $100,000 per year for ISMP Port monitoring and $700,000 for ISMP Onboard observers. Alternative assessment frequencies of 1, 3 and 5 years were explored. The default period between ERAs was five years as stipulated by AFMA but an alternative ERA frequency of 10 years was explored. FIS frequencies of 2 and 3 years were explored.

It must be noted that these costs only include regular assessment-related costs that can be directly attributable to annual monitoring and assessment, and do not include other overarching management costs. In particular, electronic monitoring costs (E-monitoring: video cameras), estimated at $643,000 per year, were not allocated to any assessment tiers for the purposes of the scenario evaluations conducted. Current E-monitoring applies mainly to only one component of the SESSF, the Gillnet Hook and Trap Fishery targeting gummy sharks, and was implemented primarily to monitor possible protected species (marine mammal) interactions. While electronic monitoring may become useful in future for the purposes of validating catch and effort logbooks, it was not clear how E-monitoring results could currently be used in a stock assessment. For the purposes of the alternative assessment scenarios evaluated here, E-monitoring costs were therefore not allocated.

The above table also shows the default annual frequency with which each data collection, data analysis, or survey activity was intended to be conducted. All of these activities were originally intended to be conducted annually, except for Orange Roughy acoustic surveys which are scheduled to be conducted every three years. These frequencies were selectable, and the effect on average annual costs of alternative frequencies (such as reducing the frequency of surveys, or some stock assessments, or data collection activities) were explored in alternative scenarios.

FIS costs are based on a winter survey only and were apportioned to species depending on the success of historical FIS surveys in providing reliable indices for 'FIS Target' species (with CV <= 0.3) and 'FIS

Secondary' species (with 0.3 < CV <=0.4), as shown in Table 20. These species designations and proportional cost allocation were selectable, but were not changed between scenarios explored. Ten percent of FIS survey costs was allocated each to Other Byproduct and Bycatch species, given that FIS surveys do generate information on byproduct and bycatch composition, provide the opportunity to sample these species if required, and may provide indices for some of these species in future. This resulted in the estimated annual FIS cost of $645,000 being allocated between species categories and species as shown in Table 20. Because the proportional FIS cost allocations were not changed, these cost allocations did not change between scenarios explored, although the averaged annual survey costs per species in Table 21 varied with survey frequency.

Table 20. Allocation of the main species surveyed by FISs to Target or Secondary categories based on survey CVs, and proportional allocation of overall FIS survey costs to the various species management categories.

Species	FIS Category
Tiger Flathead	Target
Pink Ling	Target
Common Sawshark	Target
Dogfishes	Target
Silver Warehou	Target
John Dory	Target
Ocean Perch	Target
Jackass Morwong	Target
Gemfish	Target
Gummy Shark	Target
Mirror Dory	Target
Blue Grenadier	Target
Redfish	Target
King Dory	Target
Speckled Stargazer	Secondary
Deepwater Flathead	Secondary
School Shark	Secondary
Frostfish	Secondary
Red Gurnard	Secondary
Blue Warehou	Secondary

Category	FIS Cost %
Target	65%
Secondary	15%
Other Byproduct	10%
Bycatch	10%

Table 21. Resulting FIS survey cost per species category, using the species classification resulting from cut-offs in Table 18 and the FIS species categorisation and cost allocation in Table 20, assuming that FIS surveys are conducted annually.

Category	FIS Cost %	Cost	# Species	Annual Cost/Species
Target	65%	$419,250	14	$29,946
Secondary	15%	$96,750	6	$16,125
Byproduct	10%	$64,500	93	$694
Bycatch	10%	$64,500	557	$116

7.3.2.3. Specification of alternative scenarios

Alternative assessment scenarios were primarily specified in terms of alternative frequency of assessments, to reflect the main change that has occurred recently in SESSF assessments: the move to multi-year TACs for many species, with assessments not being conducted annually. Furthermore, some scenarios explored decreasing the frequency of fishery surveys, or of selected data analysis, or data collection activities, to examine the effect on average annual costs. In addition to exploring alternative frequencies for the various cost components, two assessment alternatives were manually specified in the spreadsheet, varying the actual assessment types applied to some species to better reflect data availability and most suitable assessment method for those species:

- Current Assessment Tiers: the assessment types as actually applied to each species in 2015 were specified, including Tier 3 (catch curve analysis) for two species;
- Alternative Assessment Tiers Option 1: the default assessment types were manually altered for a number of species to reflect the preferred and most likely methods to be applied to each species, based on what is known regarding data availability to support each assessment type, and limitations on the capacity to conduct large numbers of Tier 5 assessments. This scenario envisages inter alia Tier 5 assessments for some default Tier 4 species for which CPUE analysis may be unreliable, and use of ERAs for most minor byproduct species, rather than Tier 5 assessments.
- Alternative data preparation responsibilities: selected assessment scenarios using the current assessment approach and alternative option 1 were re-evaluated using reduced costs as a result of AFMA assuming responsibility for aspects of data services and standardisation.

The following assessment scenarios provide a broad range of potential options for monitoring and assessment in the SESSF. For each scenario a description of the monitoring and assessment frequency and type is provided together with the associated costs and trade-offs. Assessment scenarios are numbered in groups relating to the high-level choice of assessment types. The dashed line triangles for each scenario illustrated shows the comparative costs under the Default scenario.

7.3.2.4. Default assessment scenario

To establish a baseline for comparison with alternative scenarios, a maximum cost 'Default' assessment scenario was specified, based on the originally intended frequency of these activities, together with default management targets and assessment methods for the various species categories, proposed by the project team. The default assessment scenario is specified in the data collection and analysis frequency Table 19 above, and in the assessment frequency, Table 22 below. This reflects the original intention to:

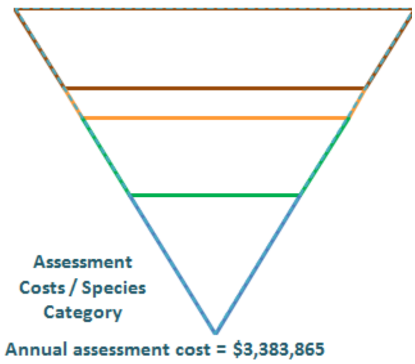
- Manage primary (target) species to an MEY target, as required under the Commonwealth Harvest Strategy Policy, using annual Tier 1 (integrated statistical) assessments;
- Manage secondary species that make a minor contribution to GVP to a MSY target, as has already been agreed for some SESSF secondary species, using annual Tier 4 (standardised CPUE trend) assessments.
- Manage Byproduct species to ensure that they remain above the Limit 90% of the time using annual Tier 5 (catch-based) assessments;
- Manage the impact on Bycatch species to ensure that they remain at low risk (with an implied likelihood of being above the limit 90% of the time) using ERAs conducted every five years.

Table 22. Proposed default (initial intended) management reference point, assessment method, and assessment frequency (years).

Species	Default Assessment Scenario		
Category	Ref Point	Assessment	Frequency
Primary	MEY	Tier 1	1
Secondary	MSY	Tier 4	1
Byproduct	>LIM	Tier 5	1
Bycatch	>LIM	ERA	5

D.1 Default Assessment Scenario; All data collected annually; All data analysed annually; FIS surveys annually; Assessments annually; ERAs every 5 years.

Category	Assess $	Assess %	% GVP
Primary	$1,468,025	43.4%	2.1%
Secondary	$424,572	12.5%	0.6%
Byproduct	$876,366	25.9%	1.3%
Bycatch	$614,903	18.2%	0.9%
Totals	$3,383,865	100%	5.0%



This Default scenario applies the initial intention of conducting all monitoring, data analysis and assessment components annually, except Orange Roughy surveys, which are conducted each three years.

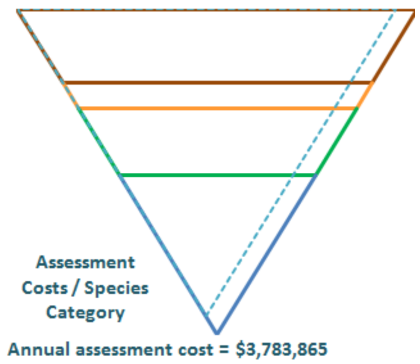
Although termed the "Default" assessment, this scenario has never actually occurred in the fishery. This scenario includes annual collection of all data types including logbooks, port-based and on-board ISMP, ageing and fishery independent survey. All of these data are prepared and analysed each year and used Tier 1, Tier 4, or Tier 5 assessments based on whether the species is a primary, secondary or byproduct species. In addition, ecological risk assessments are conducted every five years to determine fishery impacts on Bycatch, TEP species, habitats and communities.

Despite the development of annual research and assessment plans, decisions about which assessments get undertaken in which year for which species can and usually does change within any year depending on management priorities, often influenced by factors such as data quality, research outcomes and stock status (if for example a stock triggers a breakout rule or falls below the limit reference point), balanced against available funds. Also, there has never been an annual fishery independent survey. Originally designed to be conducted during the summer and winter each year, cost limitations has restricted the FIS to being run only ever second year since its inception during 2008 and only winter surveys were conducted subsequent to 2012. Nonetheless, we have used the initially intended default scenario as a way of benchmarking monitoring and assessment costs and trade-offs against alternative scenarios.

Increased Observer coverage scenario

I.1 Default Assessment Scenario; ISMP observer costs doubled; All data collected annually; All data analysed annually; FIS surveys annually; Assessments annually; ERAs every 5 years. The dotted triangle shows scenario D.1 for comparison.

Category	Assess $	Assess %	% GVP
Primary	$1,523,771	40.3%	2.2%
Secondary	$435,019	11.5%	0.6%
Byproduct	$917,635	24.3%	1.3%
Bycatch	$907,440	24.0%	1.3%
Totals	$3,783,865	100%	5.5%

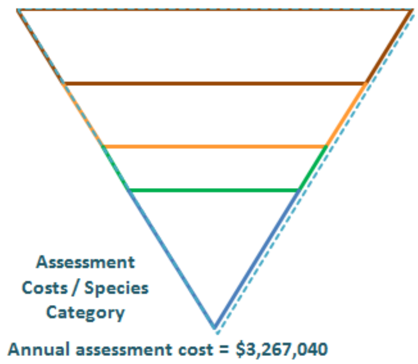


This scenario uses the same settings as the Default Scenario D.1, except that ISMP Port and Onboard observer costs were doubled, to emulate a doubling in observer coverage.

Current assessment scenarios

C.1 Current Assessment Scenario; All data collected annually; All data analysed annually; FIS surveys annually; Assessments annually; ERAs every 5 years. The dotted triangle shows scenario D.1 for comparison.

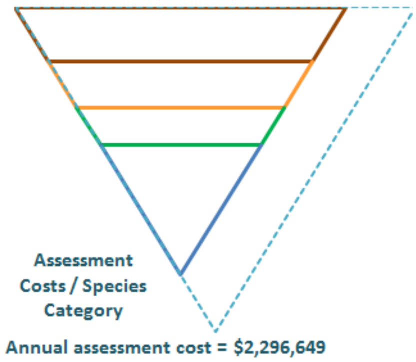
Category	Assess $	Assess %	% GVP
Primary	$1,351,628	41.4%	2.0%
Secondary	$862,993	26.4%	1.3%
Byproduct	$441,483	13.5%	0.6%
Bycatch	$610,935	18.7%	0.9%
Totals	$3,267,040	100%	4.8%



This scenario uses the same settings as the Default Scenario D.1, with all costs incurred annually except Orange Roughy surveys. However, instead of default assessment tiers, it uses the actual assessment Tiers as currently applied to the various species. Since the recent introduction of MYTACs for most of the quota species, this scenario is also not currently applicable, with many assessments now being conducted each three years. FIS surveys are also not conducted annually.

C.2 Current Assessment Scenario; All data collected annually; All data analysed annually; FIS surveys every 2 years; Assessments every 3 years; ERAs every 5 years. The dotted triangle shows scenario D.1 for comparison.

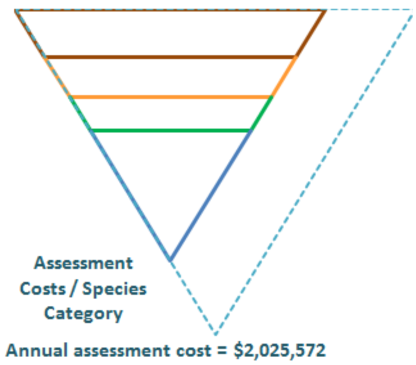
Category	Assess $	Assess %	% GVP
Primary	$840,792	36.6%	1.2%
Secondary	$556,134	24.2%	0.8%
Byproduct	$359,047	15.6%	0.5%
Bycatch	$540,676	23.5%	0.8%
Totals	$2,296,649	100%	3.4%



This scenario is the closest to 2015 current practice in terms of assessment tiers and scheduling of all components. There is annual data collection from logbooks, ISMP, and ageing with the FIS surveys run every second year (compared to annually in C.1). The species assessments are conducted every three years with multi-year TACs in the interim, and can be staggered across the years to spread costs. All data collection and analysis costs would be incurred every year. This would mean that data methods, discard estimates, length frequency, ageing and CPUE standardisation would still be available for evaluating triggers or breakout rules.

C.3 Current Assessment Scenario; All data collected annually; Data Methods, Ageing and Standardisation every 3 years; FIS surveys every 2 years; Assessments every 3 years; ERAs every 5 years. The dotted triangle shows scenario D.1 for comparison.

Category	Assess $	Assess %	% GVP
Primary	$701,647	34.6%	1.0%
Secondary	$471,777	23.3%	0.7%
Byproduct	$311,473	15.4%	0.5%
Bycatch	$540,676	26.7%	0.8%
Totals	$2,025,572	100%	3.0%

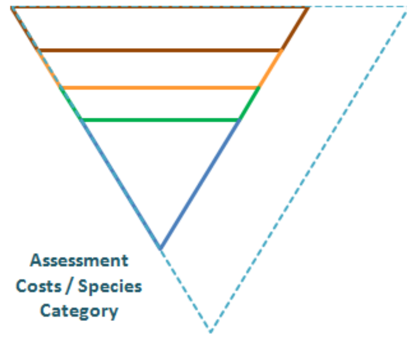


This scenario is similar to current practice Scenario C2, but assumes that Data Methods, Ageing and CPUE Standardisation will only take place every three years, to coincide with the need for these data for assessments. This would mean that results of these analyses would not be available annually for use in evaluating triggers or breakout rules. It would also make staggering of assessments difficult, as data preparation, ageing and standardisation would need to be conducted for the species to be assessed. All data collection would still be conducted annually.

The other aspect of this approach is that the data analysis and assessment research provider would be subject to two years of zero capacity requirement to one year of extensive capacity requirement, with significant implications for retaining and providing appropriate human resources.

C.4 Current Assessment Scenario; All data collected annually; Data Methods, Ageing and Standardisation every 3 years; FIS surveys every 2 years; Assessments every 5 years; ERAs every 10 years. The dotted triangle shows scenario D.1 for comparison.

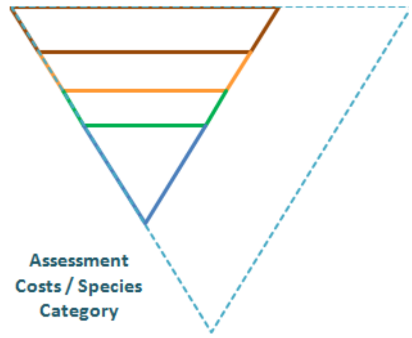
Category	Assess $	Assess %	% GVP
Primary	$616,388	32.8%	0.9%
Secondary	$430,827	22.9%	0.6%
Byproduct	$306,062	16.3%	0.4%
Bycatch	$526,960	28.0%	0.8%
Totals	$1,880,237	100%	2.8%



This scenario retains the three-yearly cycle of Data Methods, Ageing and CPUE Standardisation, but also doubles the period between assessments to five years, and that between ERAs to 10 years. The same limitations as in Scenario C.3 will apply regarding lack of analyses in intervening years for evaluation of triggers or breakout rules, as well as the same difficulties with scheduling of assessments and staff capacity. In addition, the gap between assessments is substantial, with updated assessments only available every five years. This would result in increased uncertainty regarding stock status between assessments, and require reduced MYTACs to maintain low risk of breaching limits.

C.5 Current Assessment Scenario; ISMP Port and ISMP Onboard data collected every 3 years; Data Methods, Ageing and Standardisation every 3 years; FIS surveys every 3 years; Assessments every 5 years; ERAs every 10 years. The dotted triangle shows scenario D.1 for comparison.

Category	Assess $	Assess %	% GVP
Primary	$564,336	37.5%	0.8%
Secondary	$380,568	25.3%	0.6%
Byproduct	$252,746	16.8%	0.4%
Bycatch	$308,516	20.5%	0.5%
Totals	$1,506,166	100%	2.2%



This is the lowest cost scenario explored using Current assessment tiers. In addition to the three-yearly analysis of some data components, five-yearly assessments and 10-yearly ERAs used in Scenario C.4, this scenario increases the gap between FIS surveys to three years, and reduces the frequency of ISMP Port and Onboard data collection to every three years to coincide with three-yearly analysis of some data components.

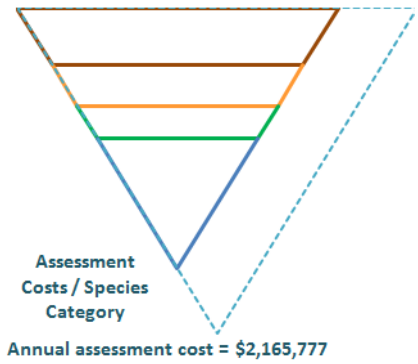
This scenario is the only one to explore actual reduction in data availability, resulting in a two-thirds reduction in observer data. It also assumes FIS surveys will only be conducted every three years, reducing the frequency of FIS survey indices. This scenario has the same limitations as Scenario C.4 regarding lack of analyses in intervening years for use in evaluating triggers and breakout rules, and substantial gaps between assessments and ERAs. In addition, lack of annual observer coverage would create difficulties in retaining experienced observer capacity.

Assessment Option 1 alternative scenarios

Under Alternative Assessment Option 1, the actual stock assessment Tiers applied to some species were manually altered from the Current assessment tiers used in the C scenarios above, to reflect data shortcomings and difficulties with some assessment methods for a few species. Changes from the Current scenarios are relatively small, but the following scenarios probably reflect the likely future assessment possibilities for those species. Other than using different assessment methods for some species, the Option 1 scenarios use the same setting as Current Scenarios C.2, C.3 and C.5, and are correspondingly numbered.

O.2 Alternative Assessment Option 1; All data collected annually; All data analysed annually; FIS surveys every 2 years; Assessments every 3 years; ERAs every 5 years. The dotted triangle shows scenario D.1 for comparison.

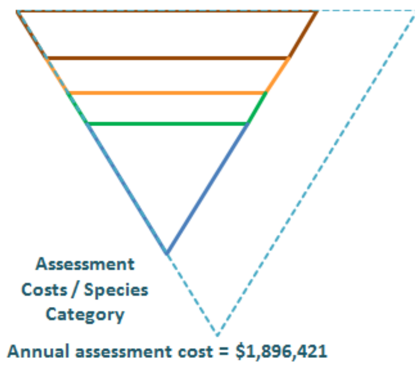
Category	Assess $	Assess %	% GVP
Primary	$846,310	39.1%	1.2%
Secondary	$473,750	21.9%	0.7%
Byproduct	$304,955	14.1%	0.4%
Bycatch	$540,762	25.0%	0.8%
Totals	$2,165,777	100%	3.2%



This scenario uses the same settings as C.2, and so closely reflects current practice, except that the assessment tiers were manually altered for a number of species to reflect the preferred and most likely methods to be applied to each species, based on what is known regarding data availability to support each assessment type, and limitations on the capacity to conduct large numbers of Tier 5 assessments.

O.3 Alternative Assessment Option 1; All data collected annually; Data Methods, Ageing and Standardisation every 3 years; FIS surveys every 2 years; Assessments every 3 years; ERAs every 5 years. The dotted triangle shows scenario D.1 for comparison.

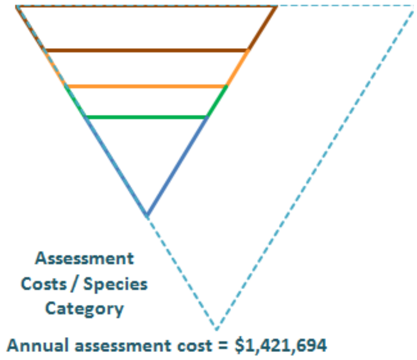
Category	Assess $	Assess %	% GVP
Primary	$667,668	35.2%	1.0%
Secondary	$405,415	21.4%	0.6%
Byproduct	$282,576	14.9%	0.4%
Bycatch	$540,762	28.5%	0.8%
Totals	$1,896,421	100%	2.8%



This scenario uses the same setting as C.3 except that the assessment tiers were manually altered for a number of species to reflect the preferred and most likely methods to be applied to each species, based on what is known regarding data availability to support each assessment type, and limitations on the capacity to conduct large numbers of Tier 5 assessments. The same limitations apply as to Scenario C.3.

O.5 Alternative Assessment Option 1; ISMP Port and ISMP Onboard data collected every 3 years; Data Methods, Ageing and Standardisation every 3 years; FIS surveys every 2 years; Assessments every 5 years; ERAs every 10 years. The dotted triangle shows scenario D.1 for comparison.

Category	Assess $	Assess %	% GVP
Primary	$551,911	38.8%	0.8%
Secondary	$332,737	23.4%	0.5%
Byproduct	$228,487	16.1%	0.3%
Bycatch	$308,558	21.7%	0.5%
Totals	$1,421,694	100%	2.1%



This scenario uses the same settings as C.5 except that the assessment tiers were manually altered for a number of species to reflect the preferred and most likely methods to be applied to each species, based on what is known regarding data availability to support each assessment type, and limitations on the capacity to conduct large numbers of Tier 5 assessments. The same limitations apply as to Scenario C.5.

Revised AFMA data preparation scenarios

Stakeholder engagement and input from project members highlighted the significant potential that automation of current data processing and analysis systems may have in improving efficiency and reducing costs. In the longer term, the proposed degree of automation for the various monitoring and assessment components, whilst not accurately defined during the course of this project, is outlined below with predicted annual costs savings (estimated by AFMA). During the course of the project, CSIRO made significant inroads into automating some of its processes and at least two other external providers put forward proposals that automated certain analyses and assessments.

Methods ($103,000 reduced to $50,000)

- Improved processes to transfer, store and quality check the data;
- Efficiencies through improved database design and management (database transfer processes, data dictionaries, protocols);
- Automated data checks, error trapping and resultant re-calculation of fishery indicators;
- More automated collection of State data.

Meeting days ($229,000 reduced to $209,000)

If automated analysis and reporting of the previous year's Logbook, CDR, ISMP and FIS data was achieved, it may negate the need for a SESSFRAG data meeting.

Standardisation ($64,000 reduced to $13,000)

Standardisation is currently a component of the CSIRO stock assessment contract. CSIRO (through Malcom Haddon) made some significant inroads into the automation of CPUE standardisation procedures and assessment against pre-defined trigger points during 2016. If these procedures are not changed from year-to-year on an ad-hoc basis (as often occurs at RAG meetings), there could be significant reductions the costs of Tier 4 and Tier 5 assessments.

Automated production of annual fishing season report

In the future, AFMA intends to produce annual fishing season reports that are available to stakeholders. There may be some additional staff costs in preparing such reports that aren't currently costed but in the longer term, it is expected that the production of these reports may be largely automated. It is likely that they will include:

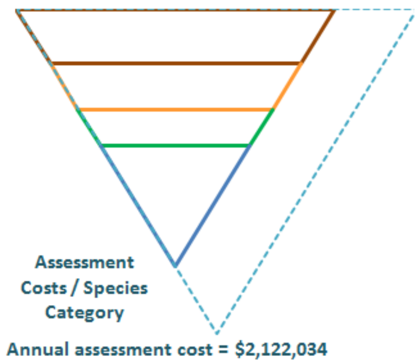
- Annual catch and effort data;
- Species composition of the retained and discarded catch;
- Indicators of fishing footprint;
- Description of observer/electronic monitoring coverage and general sampling methods;
- Length / age sampling frequency and coverage;
- Automated reporting of discarding and TEP interactions (required by regulation for AFMA and Environment Department).

Up-front costs

There will be initial up-front costs in implementing these automated systems. Some of this work has already begun in the current AFMA/CSIRO processes. AFMA has indicated, however, that a significant component of these up-front costs are being covered by an internal project which was already underway when the current project finished. This has potential benefits to all AFMA fisheries – not just the SESSF, so these costs have not been included

AC.2 Current Assessment Scenario; All data collected annually; All data analysed annually; FIS surveys every 2 years; Assessments every three years; ERAs every 5 years; AFMA automates certain aspects of data preparation and reporting. The dotted triangle shows scenario D.1 for comparison.

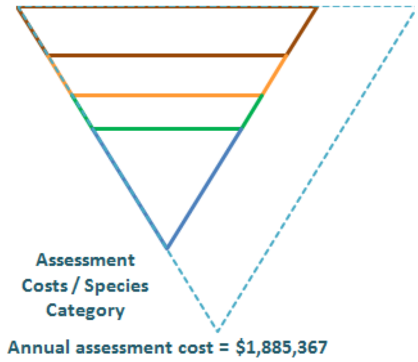
Category	Assess $	Assess %	% GVP
Primary	$809,804	38.2%	1.2%
Secondary	$520,950	24.5%	0.8%
Byproduct	$328,336	15.5%	0.5%
Bycatch	$462,945	21.8%	0.7%
Totals	$2,122,034	100%	3.1%



This scenario uses the same settings as the current practice scenario C2, but with AFMA assuming responsibility for automating certain aspects of data preparation and reporting as outlined above. .

AC.3 Current Assessment Scenario; All data collected annually; Data Methods, Ageing and Standardisation every 3 years; FIS surveys every 2 years; Assessments every 3 years; ERAs every 5 years; AFMA automates certain aspects of data preparation and reporting. The dotted triangle shows scenario D.1 for comparison.

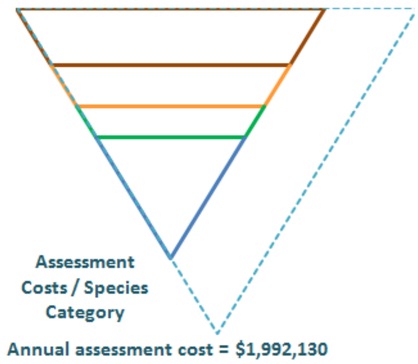
Category	Assess $	Assess %	% GVP
Primary	$683,403	36.2%	1.0%
Secondary	$450,612	23.9%	0.7%
Byproduct	$288,408	15.3%	0.4%
Bycatch	$462,945	24.6%	0.7%
Totals	$1,885,367	100%	2.8%



This scenario uses the same settings as the current practice scenario C3 (with some aspects of data preparation only being done every 3 years), but with AFMA assuming responsibility for automating certain aspects of data preparation and reporting.

AO.2 Alternative Assessment Option 1; All data collected annually; All data analysed annually; FIS surveys every 2 years; Assessments every 3 years; ERAs every 5 years; AFMA automates certain aspects of data preparation and reporting. The dotted triangle shows scenario D.1 for comparison.

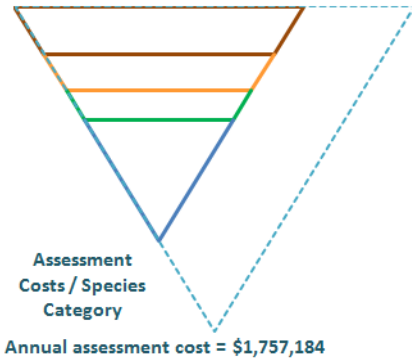
Category	Assess $	Assess %	% GVP
Primary	$799,728	40.1%	1.2%
Secondary	$453,447	22.8%	0.7%
Byproduct	$275,924	13.9%	0.4%
Bycatch	$463,031	23.2%	0.7%
Totals	$1,992,130	100%	2.9%



This scenario uses the same settings as alternative assessment option O2, which has the assessment tiers manually altered for a number of species to reflect the preferred and most likely methods to be applied to each species, based on what is known regarding data availability to support each assessment type, and limitations on the capacity to conduct large numbers of Tier 5 assessments, with AFMA assuming responsibility for automating certain aspects of data preparation and reporting.

AO.3 Alternative Assessment Option 1; All data collected annually; Data Methods, Ageing and Standardisation every 3 years; FIS surveys every 2 years; Assessments every 3 years; ERAs every 5 years; AFMA automates certain aspects of data preparation and reporting. The dotted triangle shows scenario D.1 for comparison.

Category	Assess $	Assess %	% GVP
Primary	$644,026	36.7%	0.9%
Secondary	$389,700	22.2%	0.6%
Byproduct	$260,428	14.8%	0.4%
Bycatch	$463,031	26.4%	0.7%
Totals	$1,757,184	100%	2.6%



This scenario uses the same settings as alternative assessment option O3, with AFMA assuming responsibility for automating certain aspects of data preparation and reporting.

7.4. Comparison of alternative assessment scenarios

Fourteen alternative assessment scenarios were explored by varying selectable settings in the spreadsheet:

- The Default assessment scenario (C.1), using proposed default assessment types for each species category, maximum assessment frequencies and resulting in maximum costs;
- One scenario (I.1) assuming a doubling in ISMP Port and Onboard levels (cost).
- Five alternatives of the Current assessment type scenario (C.1 - C.5), exploring less frequent FIS surveys, assessment, data analysis and data collection.
- Three alternatives of alternative assessment type Scenario 1 (O.2, O.3, O.5), exploring the same less frequent FIS surveys, assessment, data analysis and data collection to the correspondingly numbered Current scenario.
- Two scenarios similar to scenarios C.2 and C.3, but with AFMA assuming responsibility for aspects of data preparation and standardisation (AC.2 and AC.3).
- Two scenarios similar to scenarios O.2 and O.3, but with AFMA assuming responsibility for aspects of data preparation and standardisation (AO.2 and AO.3).

These alternative scenarios were chosen to sequentially explore a stepped reduction in the frequency of assessments, surveys, data analysis or data collection. Between each scenario, the frequency of one or two key cost components was reduced, from reduction in assessment and survey frequency, to reduction in frequency of some data analyses, to further assessment frequency reduction, to reduction in observer data collection. A brief description of the various scenarios is provided in Table 23. Details of the assessment costs for the 14 alternative assessment scenarios are summarised in Table 24. 'Data Frequency' refers to the annual frequency with which ISMP observer data are collected. 'Analysis Frequency' refers to the annual frequency with which data methods, ageing and standardisation analyses are conducted.

Table 23. Brief description of scenarios. C.2 generally reflects the current assessment and monitoring situation. Bold text highlights the stepped change from the previous option.

	Assessment Scenario	Description
I.1	ISMPx2	Explores costs of doubled observer coverage.
D.1	Original Default	Annual monitoring; Annual FIS; Assessment using default species classifications & assessment Tiers, 5-year ERAs
C.1	Current	Annual monitoring; Annual FIS; Assessment using actual Tiers as currently applied by the RAGs, 5-year ERAs
→C.2	**Current**	**Annual monitoring; 2-year FIS; Current RAG Assessment Tiers and 3-year MYTACs, 5-year ERAs**
C.3	Current	Annual monitoring; 2-year FIS; **3-year Data Methods, Ageing & CPUE Standardisation**; Current RAG Assessment Tiers and 3-year MYTACs, 5-year ERAs
C.4	Current	Annual monitoring; 2-year FIS; 3-year Data Methods, Ageing & CPUE Standardisation; Current RAG Assessment Tiers and **6-year MYTACs; 10-year ERAs**
C.5	Current	Annual logbook monitoring; **3-year ISMP; 3-year FIS**; 3-year Data Methods, Ageing & CPUE Standardisation; Current RAG Assessment Tiers and 6-year MYTACs; 10-year ERAs
O.2	Option 1	Annual monitoring; 2-year FIS; **Modified Assessment Tiers** and 3-year MYTACs, 5-year ERAs
O.3	Option 1	Annual monitoring; 2-year FIS; 3-year Data Methods, Ageing & CPUE Standardisation; **Modified Assessment Tiers** and 3-year MYTACs, 5-year ERAs
O.5	Option 1	Annual logbook monitoring; 3-year ISMP; 3-year FIS; 3-year Data Methods, Ageing & CPUE Standardisation; **Modified Assessment Tiers** and 6-year MYTACs; 12-year ERAs
AC.2	Current + AFMA	Annual monitoring; 2-year FIS; **Annual AFMA automated analysis and reporting**; Current RAG Assessment Tiers and 3-year MYTACs, 5-year ERAs
AC.3	Current + AFMA	Annual monitoring; 2-year FIS; **Annual AFMA automated analysis and reporting**;3-year Data Methods, Ageing & CPUE Standardisation; Current RAG Assessment Tiers and 3-year MYTACs
AO.2	Option 1 + AFMA	Annual monitoring; 2-year FIS; **Annual AFMA automated analysis and reporting;** Modified Assessment Tiers and 3-year MYTACs, 5-year ERAs
AO.3	Option 1 + AFMA	Annual monitoring; 2-year FIS; **Annual AFMA automated analysis and reporting;** 3-year Data Methods, Ageing & CPUE Standardisation; Modified Assessment Tiers and 3-year MYTACs, 5-year ERAs

Table 24. Summary of alternative assessment scenario specifications and resulting estimated annual assessment costs, % of estimated GVP spent on assessments, and cost savings compared to the highest cost Default scenario D.1. 'Data Frequency' refers to the annual frequency with which data are collected. 'Analysis Frequency' refers to the annual frequency with which data are analysed. Yellow highlighted cells show components that change from the Default scenario with each step. Scenario I.1 explores costs of doubled observer coverage. The frequency of only some elements of Data Collection and Data Analysis are changed under scenarios 2.4, 2.5 and 3.5 (see footnote). Bolded Scenario C.2 is closest to actual current practice. Under scenarios AC.3, AC.5, AO.3 and AO.5, AFMA automates certain aspects of data preparation and reporting.

Assessment Scenario		Data Frequency	Analysis Frequency	FIS Frequency	ORH Survey Frequency	Assessment Frequency	ERA Frequency	Annual Cost	% GVP	Cost Saving
I.1	ISMPx2	x2	1	1	3	1	5	$3,783,865	5.5%	-$400,000
D.1	Default	1	1	1	3	1	5	$3,383,865	5.0%	$0
C.1	Current	1	1	1	3	1	5	$3,267,040	4.8%	$116,826
→C.2	**Current**	**1**	**1**	**2**	**3**	**3**	**5**	**$2,296,649**	**3.4%**	**$1,087,216**
C.3	Current	1	3 *	2	3	3	5	$2,025,572	3.0%	$1,358,293
C.4	Current	1	3 *	2	3	5	10	$1,880,237	2.8%	$1,503,629
C.5	Current	3 ‡	3 *	3	3	5	10	$1,506,166	2.2%	$1,877,699
O.2	Option 1	1	1	2	3	3	5	$2,165,777	3.2%	$1,218,088
O.3	Option 1	1	3 *	2	3	3	5	$1,896,421	2.8%	$1,487,444
O.5	Option 1	3 ‡	3 *	3	3	5	10	$1,421,694	2.1%	$1,962,171
AC.2	Current+	1	1	2	3	3	5	$2,122,034	3.1%	$1,261,831
AC.3	Current+	1	3 *	2	3	3	5	$1,885,367	2.8%	$1,498,498
AO.2	Option 1+	1	1	2	3	3	5	$1,992,130	2.9%	$1,391,735
AO.3	Option 1+	1	3 *	2	3	3	5	$1,757,184	2.6%	$1,626,681

* Only Ageing, Data Methods and Standardisation; all other data analysed annually

‡ Only ISMP Port and ISMP Onboard' all other data collected annually

+ AFMA assumes responsibility for aspects of Data Services and Standardisation, with changes in staff and meeting costs

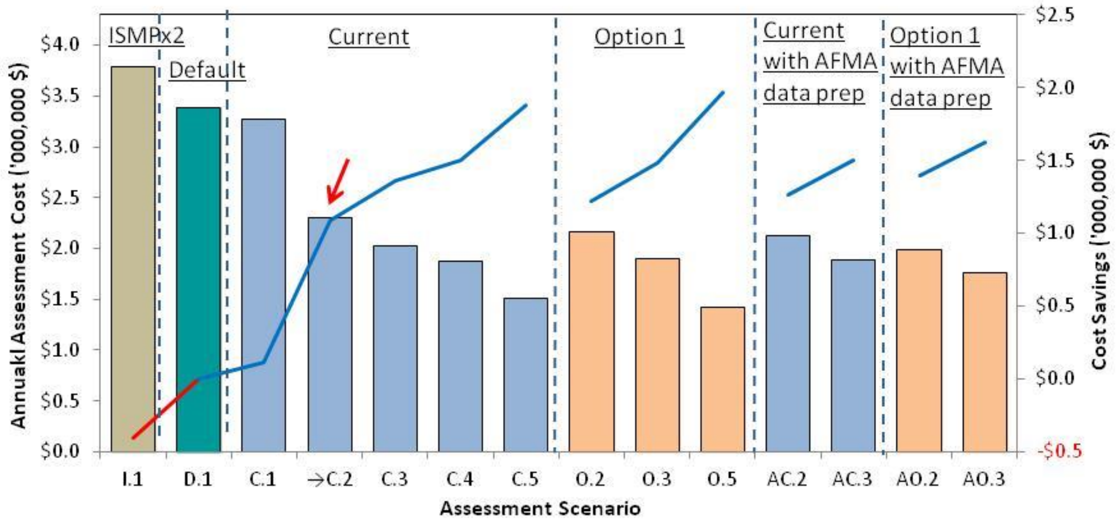


Figure 35. Comparison of estimated costs (columns) and cost savings (lines) of alternative assessment scenarios, as summarised in Table 23 and Table 24. The red arrow indicates the scenario (C.2) closest to current practice.

Total assessment costs and cost savings in comparison to the Default scenario are depicted in Figure 35. Total estimated annual monitoring and assessment costs under the scenarios explored, excluding E-monitoring, range from a maximum of $3,383,865 (5.0% of GVP) for the Default scenario, to a minimum of $1,506,166 2.2% of GVP) for Scenario C.5. Maximum cost savings compared to the Default scenario of $1,877,699 are achieved under Scenario C.5, but with reduction in data (ISMP monitoring), FIS surveys only every 3 years, 5 years between assessments and 10 years between ERAs.

Assumption of responsibility by AFMA for some aspects of data preparation and standardisation reduces annual costs by about a further $174,000 for scenarios C.2 and O.2, and $140,000 for scenarios C.3 and O.3.

Addition of estimated annual E-monitoring costs of $643,000 to the total cost for each scenario would increase the estimated total annual expenditure on monitoring and assessment to $4,026,865 (5.9% of GVP) for default Scenario D.1, and to $2,149,166 (3.1% of GVP) for Scenario C.5.

7.4.1. Alternative scheduling of assessments

The recent move to conducting surveys and stock assessments less frequently than every year provides an opportunity to stagger the scheduling of assessments to spread the cost more evenly between years, rather than accruing all assessment costs in a single year. Assessment scheduling can be shifted to reduce assessment costs in years when FIS or Orange Roughy surveys are to be conducted.

For example, two ways in which monitoring and assessment could be allocated to the same C.2 scenario are show below. Conducting all of the assessments every third year results in large variations of costs from year to year (Table 25, Figure 36), compared with an spreading of assessments that avoids years with high survey costs (Table 26, Figure 37).

Other current assessment scenarios with scheduling of data collection and assessments allocated to avoid years with high survey costs and reduce inter-annual variation in %GVP spent are shown in Figure 38 - Figure 40.

Table 25. C2 with all assessments conducted every third year.

Year	Unit Cost	Total Cost	Total Cost	1 2017	2 2018	3 2019	4 2020	5 2021	6 2022	Annual Avg Cost
Logbooks, CDRs	$220,000		$220,000	$220,000	$220,000	$220,000	$220,000	$220,000	$220,000	$220,000
ISMP Port and Onboard	$400,000		$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000
E-monitoring	$643,000									
Services, Staff, Meetings	$474,000		$474,000	$474,000	$474,000	$474,000	$474,000	$474,000	$474,000	$474,000
Ageing, Methods, Standardisation	$406,615		$406,615	$406,615	$406,615	$406,615	$406,615	$406,615	$406,615	$406,615
FIS survey	$645,000		$645,000	$645,000		$645,000		$645,000		$322,500
Orange roughy survey	$355,000		$355,000	$355,000			$355,000			$118,333
Tier 1	$70,667	13	$918,671	$918,671			$918,671			$306,224
Tier 3	$4,000	2	$8,000	$8,000			$8,000			$2,667
Tier 4	$3,257	14	$45,598	$45,598			$45,598			$15,199
Tier 5	$3,257	0	$0							
ERA	$157,000	641	$157,000	$157,000						$26,167
Annual Total Cost				$3,629,884	$1,500,615	$2,145,615	$2,827,884	$2,145,615	$1,500,615	$2,291,705
Annual % GVP				5.3%	2.2%	3.1%	4.1%	3.1%	2.2%	3.4%

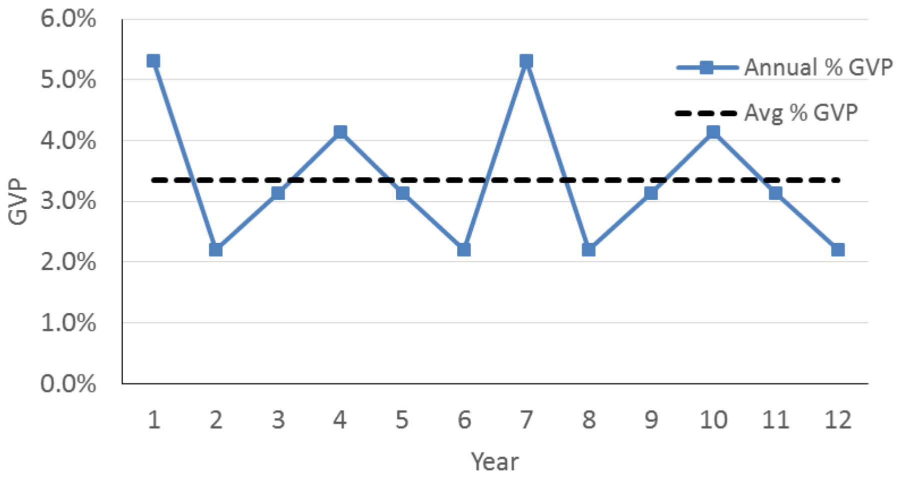


Figure 36. C2 with all assessments conducted every third year.

Table 26. C2 with assessments allocated around years with high survey costs.

Year	Unit Cost	Total Cost	Total Cost	1 2017	2 2018	3 2019	4 2020	5 2021	6 2022	Annual Avg Cost
Logbooks, CDRs	$220,000		$220,000	$220,000	$220,000	$220,000	$220,000	$220,000	$220,000	$220,000
ISMP Port and Onboard	$400,000		$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000
E-monitoring	$643,000									
Services, Staff, Meetings	$474,000		$474,000	$474,000	$474,000	$474,000	$474,000	$474,000	$474,000	$474,000
Ageing, Methods, Standardisation	$406,615		$406,615	$406,615	$406,615	$406,615	$406,615	$406,615	$406,615	$406,615
FIS survey	$645,000		$645,000	$645,000		$645,000		$645,000		$322,500
Orange roughy survey	$355,000		$355,000	$355,000			$355,000			$118,333
Tier 1	$70,667	13	$918,671		$494,669	$212,001	$212,001	$282,668	$636,003	$306,224
Tier 3	$4,000	2	$8,000		$4,000	$4,000		$4,000	$4,000	$2,667
Tier 4	$3,257	14	$45,598		$22,799	$22,799		$22,799	$22,799	$15,199
Tier 5	$3,257	0	$0							
ERA	$157,000	641	$157,000		$157,000					$26,167
Annual Total Cost				$2,500,615	$2,179,083	$2,384,415	$2,067,616	$2,455,082	$2,163,417	$2,291,705
Annual % GVP				3.7%	3.2%	3.5%	3.0%	3.6%	3.2%	3.4%

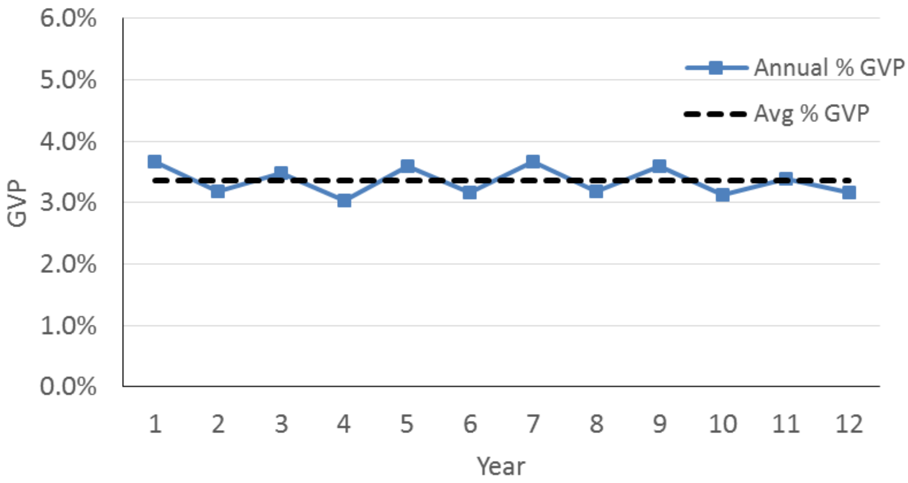


Figure 37. C2 with assessments allocated around years with high survey costs.

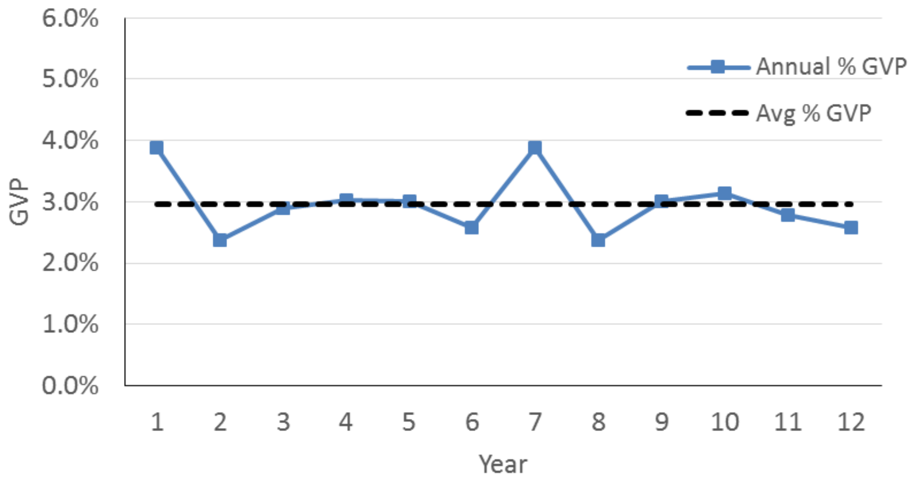


Figure 38. C3 with assessments allocated around years with high survey costs.

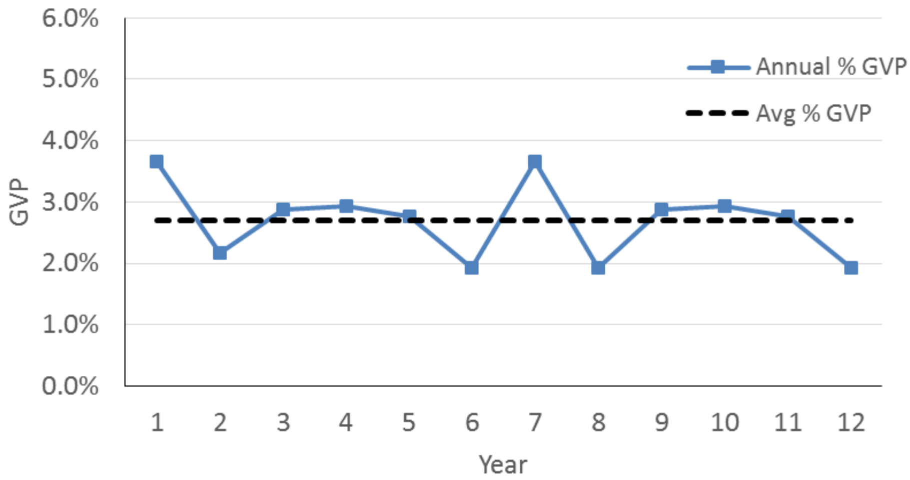


Figure 39. C4 with assessments allocated around years with high survey costs.

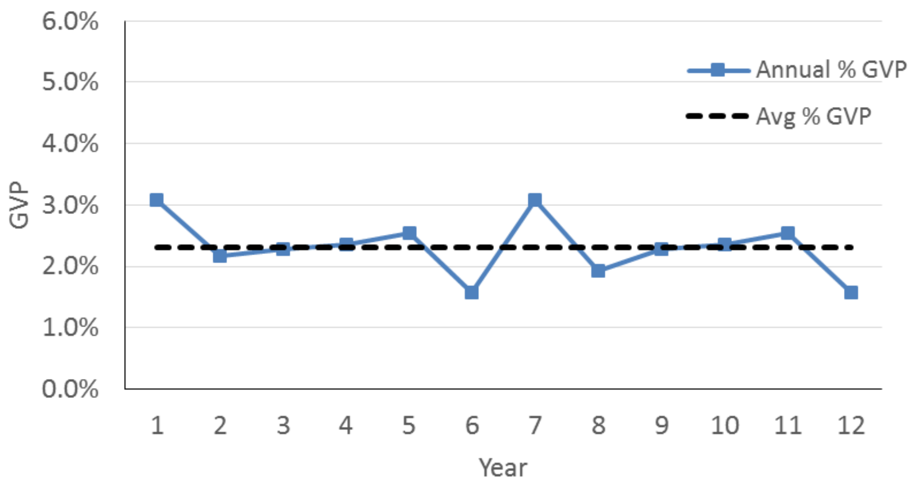


Figure 40. C5 with data collection and assessments allocated around years with high survey costs.

7.4.2. Discussion

There are a number of options available for reducing stock assessment (data collection, data analysis, stock assessments and survey) costs in the SESSF. The main options relate to reducing the frequency with which some of these assessment components are conducted. This has already occurred with the move to multi-year TACs (MYTACs) for many species, with reduction of assessment frequency to every three or five years. FIS survey frequency has also been reduced from one to two years. Further options relate to changing the type of assessment applied to different species, with an associated change in the data requirements and assessment costs under different tiers. This has also occurred for some species, such as where Tier 1 or Tier 3 assessments were found to be unreliable or not possible due to data shortcomings, resulting in application of Tier 4 assessments instead. More recently, low information for mixed oreo-dories resulted in the first application of a catch-based Tier 5 approach to provide RBC advice for these species.

There are inevitable trade-offs in conducting assessments or surveys less frequently, or moving to lower information assessments with associated reduction in data collection. The key trade-offs are identified and discussed below.

7.4.2.1. Trade-offs under alternative assessment scenarios

Comparison of the results of alternative scenarios summarised in Table 23, Table 24 and Figure 35 shows a number of key conclusions:

The Default scenario (particularly surveys and assessments every year, Tier 1 for all Primary species, Tier 4 for all Secondary species), is not considered to be affordable or feasible at current fishery GVP, so likely options are those from Scenario C.2 onwards.

There have already been significant cost savings in comparison with the Default (initially intended, highest cost) scenario, following reduction of the frequency of stock assessment for many species, and reducing FIS survey frequency from one to two years (and winter only). Excluding E-Monitoring costs, Scenario C.2 (the closest scenario to current practice) has an estimated average annual cost of \$2,297,539 (3.4% of GVP), compared with \$3,378,623 (4.9% of GVP) for the Default scenario.

Further reductions in monitoring and assessment costs require either: further reduction in the frequency of stock assessments; further reduction in frequency of surveys; or reduction in the frequency of some components of the fixed costs of data analysis or data collection.

Each of these options comes at a cost of reduction in data, or increased uncertainty and risk as a result of less frequent assessments. Reduction in the frequency of data analysis (Scenarios C.3, C.4, C.5) means that the results of these analyses will not be available in years between assessments for use in, for example, evaluation of triggers and breakout rules.

Reductions in frequency of ISMP monitoring will result in reductions in observer data and lack of observer data on, for example, protected species interactions or bycatches in alternate years. Further reduction in assessment frequency will result in increased uncertainty between assessments and a likely need to reduce TACs to prevent increased risk to the sustainability of fish stocks. The appropriate TAC reduction levels required to maintain low risk of breaching the limit will need to be determined using MSE testing of alternative assessment frequencies.

There are only minor cost-savings to be made by moving to alternative assessment Option 1, using lower information tiers for some species. However, some of the alternative assessment methods proposed under Option 1 are likely to be unavoidable given limitations on data and assessment capacity for many of the Byproduct species.

7.4.2.2. Lost opportunity costs under alternative scenarios

One of the potential trade-offs that arises when moving from high information assessments (Tier 1) to lower information (Tiers 3, 4 or 5) assessments, is the potential lost opportunity cost that is expected to arise as a result of lower recommended biological catches (RBCs) and TACs under lower information assessments. Lower information assessments are inherently more uncertain, and this uncertainty translates into a requirement to reduce TACs to maintain a < 1 in 10-year risk of breaching the Limit Reference Point, and more so if assessments are not conducted annually.

This requirement to decrease TACs when assessment is uncertain has been recognised in the SESSF for some time and the SESSF Resource Assessment Groups have been advised to apply discount factors to RBCs derived using Tier 3 and 4 assessments. Preliminary precautionary discount factors were proposed at 5% for Tier 3 and 15% for Tier 4. These proposed discount factors have not yet been tested using management strategy evaluation and the initial MSE testing of each harvest strategy was conducted without the inclusion of the discount factors. However, for the purpose of providing some exploratory examples of what the estimated lost opportunity costs might be under alternative assessment scenarios, it was assumed that the TAC that could be achieved under Tier 3 or Tier 4 assessments would be that achieved under Tier 1, with application of a discount factor of 5% for Tier 3, and 15% for Tier 4.

Tier 5 has only recently been applied to one SESSF stock, so no discount factor was previously proposed for this Tier assessment. For the purposes of exploratory analysis, it was assumed that Tier 5 would attract a further 10% reduction below Tier 4, giving a discount factor of 25%. The resulting % TACs achieved under alternative Tiers in comparison with Tier 1 are summarised in Table 27, together with estimated combined annual assessment-related costs per tier under assessment Scenario C.2, being the scenario closest to current practice.

Table 27. Assumed % RBCs (Tier 1 minus discount factor) and overall costs per assessment Tier used for comparative analysis of Revenue, Costs and potential Lost Opportunity Cost under alternative assessment scenarios. Estimated costs are those under Scenario C.2 in Table 23, being the scenario closest to current practice.

Assessment level	% RBC	Assessment-related cost
Tier 1	100%	$86,477
Tier 3	95%	$51,067
Tier 4	85%	$29,913
Tier 5	75%	$23,174

These assessment costs and achieved % TACs were applied to the 23 main SESSF quota species (excluding species on incidental or bycatch TACs), together with data on 2015-16 TACs, average 2012-14 catches, and GVP based on 2010-14 average prices, to estimate combined annual Revenue, Costs, Retained Earnings, and potential Lost Opportunity Costs for these species, either assuming that the full TACs are caught, or assuming the current levels of TAC undercatch.

Assuming the full 2015-16 TACs were caught

Initial analysis assumed that the full TACs were caught, to estimate what the maximum lost opportunity costs might be if catches were only limited by the TACs, and the TACs, in turn, were dependent on the assessments methods used and therefore, the discount factors applicable to each tier. Six alternative assessment scenarios were explored: The 'Default', 'Current' and 'Option 1' scenarios described in Table 23 and Table 24, and three extreme scenarios using either all Tier 1, all Tier 4, or all Tier 5 assessments. Results of this analysis are shown in Table 28 and Figure 41.

Table 28. Comparison of hypothetical 2015-16 RBCs; Assessment Costs; Revenue assuming the full TACs are caught; and Balances (Revenue - Cost) under a range of alternative assessment scenarios. 'Default', 'Current' and Option 1' are the alternative assessment scenarios described in Table 23 and Table 24.. Potential lost Opportunity Costs are calculated as the difference between the Balance under each scenario, with that theoretically achievable using All Tier 1 assessments.

Scenario	2015-16 TAC	Cost	Revenue	Balance	Opportunity Cost
All Tier 1	27,899	$1,988,966	$104,788,475	$102,799,509	$0
All Tier 4	23,714	$688,007	$89,070,204	$88,382,196	-$14,417,313
All Tier 5	20,924	$533,007	$78,591,356	$78,058,350	-$24,741,159
Default	26,540	$1,226,685	$100,743,724	$99,517,039	-$3,282,470
Current	27,251	$1,352,512	$102,523,834	$101,171,322	-$1,628,187
Option 1	25,710	$1,016,560	$97,317,890	$96,301,330	-$6,498,179

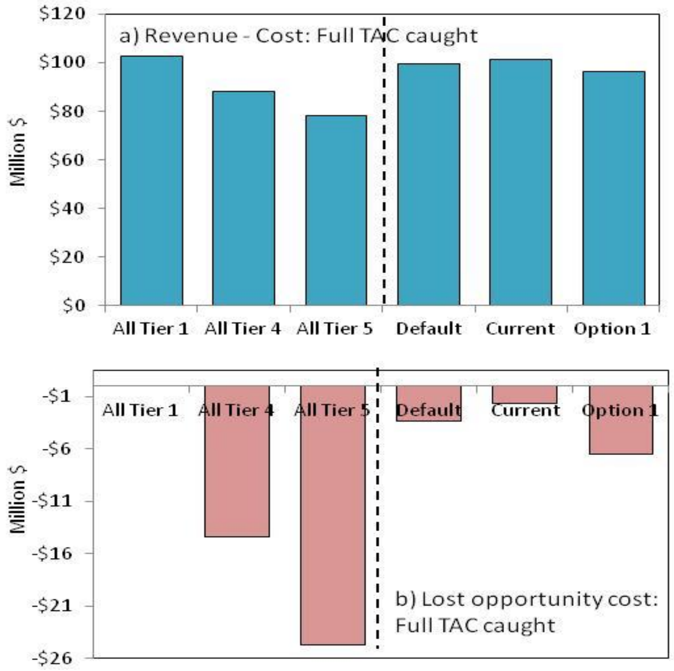


Figure 41. Comparison of a) Retained earnings (Revenue - Assessment Costs) under alternative assessment scenarios; and b) Resulting lost opportunity costs compared to conducting All Tier 1 assessments (data from Table 28).

Under the assumptions of this analysis, there would be substantial lost opportunity costs in moving from Tier 1 to Tiers 4 and 5, as a result of the discount factors and reduced TACs under the lower information tiers. Despite Tier 4 and 5 assessment costs being substantially lower than for Tier 1 (35% and 27% of Tier 1 costs respectively, from Table 28), there would be estimated lost opportunity costs of $14.4 million and $24.7 million (compared with a maximum retained earnings of $102.8 million under all Tier 1), if the full TACs were caught (Table 28 and Figure 41). Note, that in referring to lost opportunity costs, we do not include the cost of mismanagement that may result from the setting of an incorrect TAC.

In comparison with these extreme and unrealistic examples (applying one particular assessment method to all species), there is less variability and lower lost opportunity costs for the more realistic 'Default', 'Current' and 'Option 1' scenarios. These achieve similar retained earnings between $96.3 million and $101.2 million, with lost opportunity costs of between $1.6 million and $6.4 million. Scenario C.2 (closest to current practice) would have the lowest lost opportunity cost ($1.6 million) under these assumptions (Table 28 and Figure 41).

Assuming the actual 2015-16 reported catches

In reality, however, SESSF TACs are currently substantially under-caught, with the 2012-14 combined landed catch of the 23 species included in these analyses being only about 48% of their combined 2015-16 TACs. Fishery Revenue is therefore far lower than would be achieved if the full TACs were caught, while assessment costs remain the same. Comparative analyses assuming the actual 2012-14 average catches, rather than the TACs, are shown in Figure 42.

When actual catches are used, retained earnings (Revenue - Assessment Costs) are far lower than would be achieved if the full TACs were caught, ranging from $53.9 million to $55.5 million across all scenarios (some 57% of retained earnings for full TACs). In particular, there is very little difference between retained earnings across the 'Default', 'Current' and 'Option 1' scenarios, which are all close to their average $55.4 million (Figure 42).

Table 29. Comparison of hypothetical 2015-16 RBCs; Assessment Costs; Revenue assuming the actual 2015-16 reported catches were caught; and Balances (Revenue - Cost) under a range of alternative assessment scenarios. 'Default', 'Current' and Option 1' are the alternative assessment scenarios described in Table 23 and Table 24. Potential lost Opportunity Costs are calculated as the difference between the Balance under each scenario, with that theoretically achievable using All Tier 1 assessments.

Scenario	2012-14 Catch	Cost	Revenue	Balance	Opportunity Cost
All Tier 1	13,084	$1,988,966	$56,716,351	$54,727,385	$0
All Tier 4	12,702	$688,007	$54,661,223	$53,973,216	-$754,169
All Tier 5	12,059	$533,007	$51,077,746	$50,544,740	-$4,182,645
Default	13,051	$1,226,685	$56,610,956	$55,384,271	$656,886
Current	13,055	$1,352,512	$56,620,559	$55,268,046	$540,662
Option 1	13,035	$1,016,560	$56,556,698	$55,540,138	$812,753

Importantly, because the TACs are being under-caught, this means that they are not limiting catches, even under low information assessment scenarios. The lost opportunity costs that should arise as a result of lower TACs under lower information assessments tiers are largely negated by the undercatches. Some lost opportunity costs remain under the assumed discount factors for the extreme All Tier 4 and All Tier 5 scenarios, but these are low, being about $4.2 million for All Tier 5 and only about $754,000 for All Tier 4.

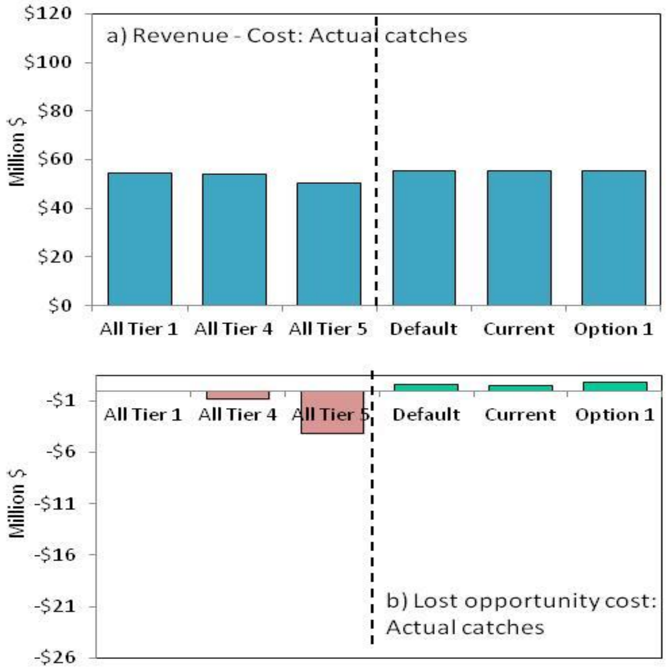


Figure 42. Comparison of a) Retained earnings (Revenue - Assessment Costs) under alternative assessment scenarios; and b) resulting lost opportunity costs compared to conducting All Tier 1 assessments (data from Table 29).

The effect of this undercatch is most striking on estimates of 'lost opportunity costs' under the 'Default', 'Current' and 'Option 1' scenarios. There are, in fact, no lost opportunity costs under these scenarios, which all provide higher retained earnings, averaging $670,000 above the All Tier 1 scenario with undercatches, essentially providing optimal assessment scenarios under the current situation of undercaught TACs. Reduced TACs resulting from use of lower information assessments are more than offset by the undercatch. This raises questions relating to the relative benefits of using higher information assessment tiers, if the higher TACs resulting from these assessments will remain under-caught, and emphasises the importance of understanding the reasons for this undercatch.

7.5. Effort and risk reduction in the SESSF

7.5.1. ERAEF risk assessments

AFMA has applied multi-level risk assessments to all Commonwealth fisheries under the *Ecological Risk Assessment for Effect of Fishing* (ERAEF) framework (Hobday *et al.,* 2007, 2011a, 2011b). Following initial level one Scale, Intensity, Consequence Analysis (SICA) risk screening, all species considered to be at high risk are subjected to level two Productivity-Susceptibility Analysis (PSA) analysis, with the next step being a level three Sustainability Assessment for Fishing Effects (SAFE) assessment. Such Ecological Risk Assessments (ERA) usually apply to data poor species whereby information on known biological characteristics (e.g. productivity) and habitat (e.g. susceptibility to fishing) influence assessment of the ecological risk presented by commercial fishing. Management action is then taken to reduce fisheries-related risk for species considered to be at high risk by ERA.

The SESSF CTS and GHaTS sectors were subject to initial PSA and SAFE analysis in 2007 (Hobday *et al.,* 2011a), with the SAFE assessments being updated in 2012 (Zhou *et al.,* 2012b). Of the 600 species included in the CTS PSA assessment, 159 were considered to be at High risk and 239 at Medium risk (Table 30). Of the 329 species in the GHaTS PSA assessment, 21 were assessed as being at High risk and 136 at Medium risk.

Table 30. Summary of results of the 2007 PSA and 2012 SAFE ERAs for the CTS and GHaTS , showing the numbers of species initially classified as Low, Medium and High risk in the PSA assessments, and the reduced numbers of species subsequently considered to be at Medium risk ($F > F_{msm}$) and High risk ($F > F_{crash}$) in the 2012 SAFE assessment.

SESSF fishery	Species category	Total Species	PSA			SAFE		
			Low	Med	High	$F > F_{msm}$	$F > F_{lim}$	$F > F_{crash}$
CTS	Target		2	11	15	0	0	0
	Byproduct		28	28	39	5	1	1
	Bycatch		98	79	99	9	6	3
	TEPs		74	121	6	0	0	0
CTS totals		600	202	239	159	20		4
GHaTS	Target		0	0	1	0	0	0
	Byproduct		57	12	11	3	0	2
	Bycatch		45	8	3	3	1	0
	TEPs		70	116	6	1	0	1
GHaTS totals		329	172	136	21	8		3

Following the 2012 update of the SAFE assessment and the initial PSA, only one byproduct and three bycatch species in the CTS (Harrison's dogfish; southern dogfish, common skate and bight skate), and two byproduct and one TEP species in the GHaTS (bronze whaler, dusky shark; white shark) were assessed as being at extreme high risk, with estimated $F > F_{crash}$. Seven CTS species and 1 GHaTS species were assessed as being at high risk ($F>F_{lim}$), and a further 14 CTS species and seven GHaTS species were evaluated as being at medium risk, with $F > F_{msy}$.

7.5.2. Reduction in effort

A key contributor to the reduction in ecological risk between the 2007 PSA and 2012 SAFE risk assessments was a purposeful reduction in fishing effort in these fisheries. The 2005 Ministerial Direction required AFMA, *inter alia*, to cease overfishing and recover overfished stocks to levels that will ensure long term sustainability, productivity and profitability. One of the actions taken to achieve this was a structural adjustment package whereby vessel licences were bought out of Commonwealth fisheries to reduce over-capitalization resulting from too many vessels in the fleet. The structural adjustment occurred from November 2005 – November 2006, resulting in a reduction in the number of vessels, and consequently in the amount of fishing effort in the SESSF from then onwards.

Figure 43 and Figure 44 show the trends in annual fishing effort (total trawl tows or gillnet sets) in the CTS and GHaTS respectively over the period 2004 – 2015, compared with the average fishing effort levels over the PSA ERA reference period of 2004 – 2007 (Penney, 2016). In each figure, upper and lower effort trigger levels are shown, indicating +- 25% and the 90% confidence intervals on the 2004 – 2007 effort reference levels.

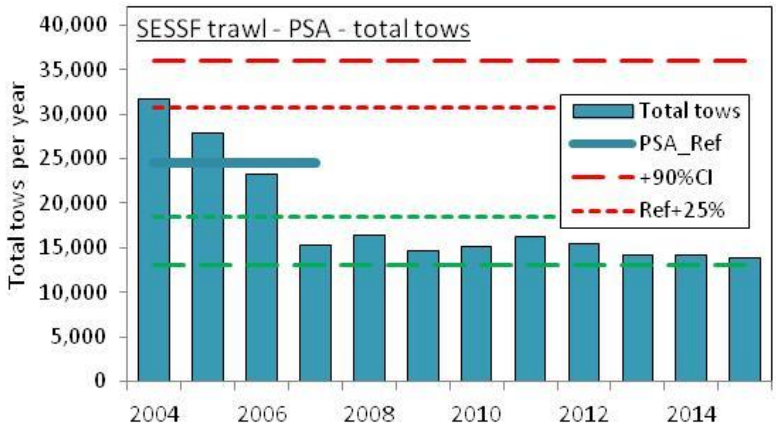


Figure 43. Trend in fishing effort (total trawl tows per year) in the SESSF CTS trawl sector between 2004 and 2015, compared with the average effort over the 2007 PSA ERA reference period of 2004 – 2007 (Penney, 2016). Dotted lines show the reference effort level +- 25% and dashed lines show the 90% CI on the effort reference level.

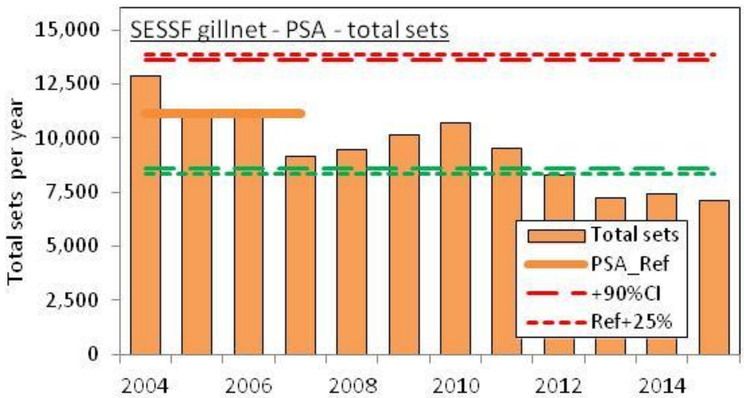


Figure 44. Trend in fishing effort (total gillnet sets per year) in the GHaTS between 2004 and 2015, compared with the average effort over the 2007 PSA ERA reference period of 2004 – 2007 (Penney, 2016). Dotted lines show the reference effort level +- 25% and dashed lines show the 90% CI on the effort reference level.

The effect of the structural adjustment buyout is evident in both fisheries, with effort dropping between 2004 and 2006 and remaining below the 2004 – 2007 average effort since then. Following a subsequent slight increase in effort up to about 2010 or 2011, effort has continued to decline in both fisheries to historically low levels. In the CTS, the number of trawl tows has remained below -25% of the PSA reference effort level since 2007 and was only slightly above the -90% CI in 2015. In the GHaTS, which had lower variance in effort over 2004 – 2007 and narrower confidence intervals, the number of gillnet sets decreased below both the -25% and -90% CI in 2012 and has continued to decrease through to 2015.

Figure 45 and Figure 46 show the trends in CTS and GHaTS fishing effort over 2004 – 2015 compared with the respective 2007 – 2010 SAFE ERA effort reference levels, +=25% and 90% CIs. Fishing effort was relatively stable in both fisheries over the SAFE reference period, resulting in substantially narrower 90% confidence intervals. As a result, ongoing effort declines resulted in effort in the GHaTS declining below the SAFE -90% CI by 2012, and in the CTS by 2013. Effort in the CTS remains slightly above the -25% effort reference level, but has almost reached this level in the GHaTS.

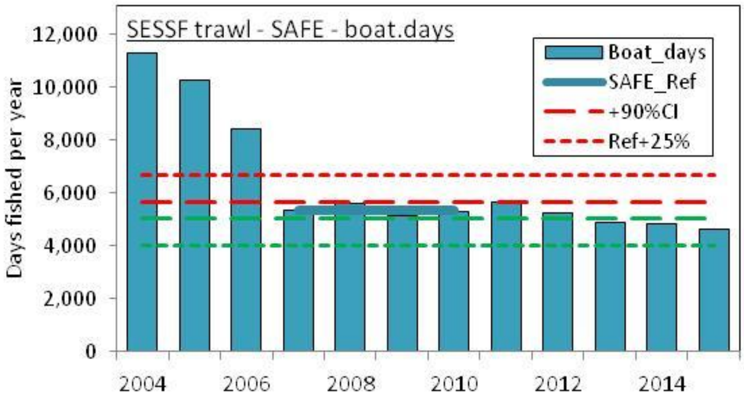


Figure 45. Trend in fishing effort (total trawl tows per year) in the CTS between 2004 and 2015, compared with the average effort over the 2012 SAFE ERA reference period of 2007 – 2010 (Penney, 2016). Dotted lines show the reference effort level +- 25% and dashed lines show the 90% CI on the effort reference level.

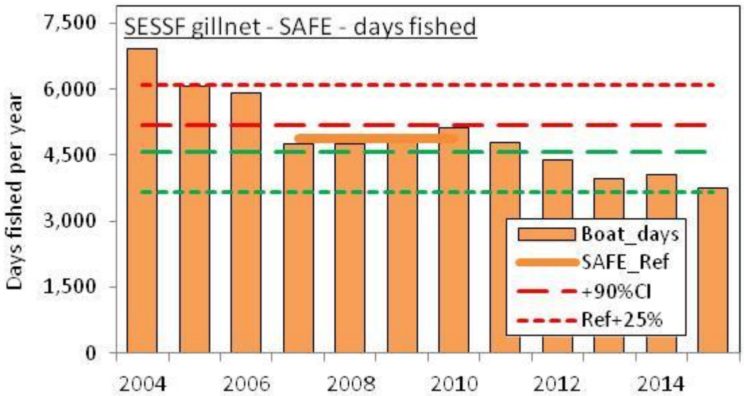


Figure 46. Trend in fishing effort (total gillnet sets per year) in the GHaTS between 2004 and 2015, compared with the average effort over the 2012 SAFE ERA reference period of 2007 – 2010 (Penney, 2016). Dotted lines show the reference effort level +- 25% and dashed lines show the 90% CI on the effort reference level.

Alternative 2015 relative effort levels (either boat.days, number of tows or sets or 0.1° fished blocks) are summarised in Table 31, expressed as percentages of the respective CTS and GHaTS 2007 PSA and 2012 SAFE average effort reference levels.

Table 31. CTS GHaTS 2015 effort levels (boat.days, number of tows or sets and 0.1° blocks fished) expressed as a percentage of the average effort levels across the reference years used in the 2007 PSA and 2012 SAFE ERAs for the CTS and GHaTS sectors of the SESSF. The relative effort levels used to evaluate scaled reductions in ERA risk are in bold.

ERA level and reference years	Sector	Boat.days fished	Number of tows or sets	0.1° fished blocks
PSA	CTS	-47%	**-44%**	-40%
(2004-2007)	GHaTS	-36%	**-36%**	-17%
SAFE	CTS	-13%	**-10%**	-21%
(2007-2010)	GHaTS	-23%	**-28%**	-18%

7.5.3. Reduction in risk

The intended outcomes of the 2005 Ministerial Direction have largely been achieved, with the reduction in fishing effort and subsequent implementation of harvest strategies and sustainable TACs (see Section 5.2 *Data collection and assessments in the SESSF*) resulting in cessation of overfishing and recovery of most stocks. The most recent Commonwealth *Fishery status reports* (ABARES, 2016) reports that all but four stocks in the CTS and GHaTS are classified as "not subject to overfishing", with Blue Warehou, Eastern Gemfish, Redfish and School Shark classified as being "uncertain whether subject to overfishing". Only Blue Warehou, Eastern Gemfish, gulper sharks, southern and western Orange Roughy, Redfish and School Shark remain classified as "Overfished". The situation continues to improve with eastern Orange Roughy changing from "uncertain if overfished" to "not overfished" between 2013 and 2014 and Blue-eye Trevalla and Pink Ling changing from "uncertain if overfishing" to "no overfishing" between 2014 and 2015, with neither of these stocks classified as being "overfished".

The reduction in fishing effort in the CTS and GHaTS has led to an overall reduction in the risk presented by these fisheries to bycatch species and to the broader ecosystem. As part of a process to improve the approach taken to risk assessment for Commonwealth fisheries, AFMA developed a guide to the *Ecological Risk Management Framework* (ERM) (AFMA, 2016). One component of that guide envisages an annual process to review fisheries indicators against chosen trigger levels, to determine whether risk profiles for a fishery may have changed sufficiently to prompt further ERA assessment.

Using the CTS and GHaTS as case studies, Penney (2016) evaluates options and provides recommendations on appropriate indicators and trigger levels for detecting change in risk in these fisheries. Fishing effort levels are used as one of the contributors to estimates of Range Overlap, used in estimation of *F* in SAFE assessments and in estimation of the Availability risk score in PSA assessments. Fishing effort is the only contributory risk factor that has changed significantly since the initial 2007 PSA risk assessments for the CTS and GHaTS and is therefore the key indicator to use to evaluate changes in risk. For the CTS and GHaTS, it makes little difference whether effort is measured as boat.days fished, total number of tows or sets or fished area (numbers of 0.1° fished blocks), as these three alternative effort measures are highly correlated (Penney, 2016).

In PSA assessment, the key risk factor Range Overlap (which determines Availability) is calculated from fished area in relation to the core distribution range of the species concerned. In the SESSF, fished area is closely correlated with fishing effort, so relative changes in fishing effort can be applied as a percentage scaling factor to the Overlap component of the Availability score, which then contributes to the Susceptibility score. If other factors such as Encounterability (depth of fishing), Post capture mortality, and gear Selectivity remain unchanged (as they have in the SESSF), then changes in effort can be applied as a scaling factor on the Susceptibility score itself. With biological productivity parameters for a species unlikely to change substantially between assessments, Productivity risk scores will remain unchanged, leaving changes in fishing effort as the key driver of potential changes in overall PSA risk. In SAFE assessments, fishing effort is the key factor in a multiplicative formula used to estimate current proxy *F*. Changes in fishing effort can therefore be applied as a percentage scaling factor directly to the estimate of *F* from the previous SAFE assessment to evaluate how fishing mortality has changed in relation to the estimated reference points F_{msm} (maximum sustainable fishing mortality) and F_{crash} (the level of *F* that will result in the stock becoming overfished) for each species.

Figure 47 and Figure 48 show the results of applying effort changes to the 2007 PSA Susceptibility scores for the CTS and GHaTS respectively (from Penney, 2016).

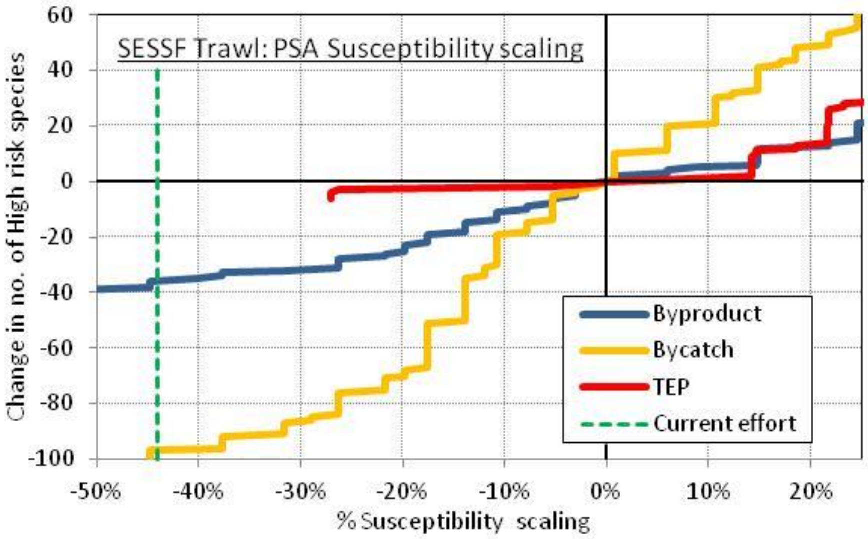


Figure 47. **Increase or reduction in the number of species potentially at High risk in the CTS as fishing effort increases or decreases, with changes in effort applied as a percentage scaling factor to the PSA Susceptibility score (Penney, 2016). The current effort level as a percentage of the 2007 PSA reference effort level is shown by the green dashed line.**

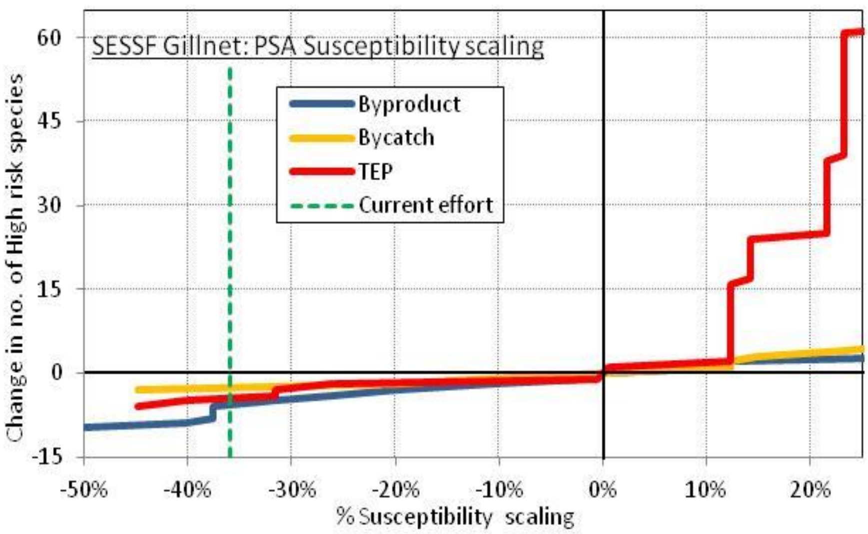


Figure 48. **Increase or reduction in the number of species potentially at High risk in the as fishing effort increases or decreases, with changes in effort applied as a percentage scaling factor to the PSA Susceptibility score (Penney, 2016). The current effort level as a percentage of the 2007 PSA reference effort level is shown by the green dashed line.**

In the CTS, fishing effort (number of trawl tows) has decreased by 44% over the 2004 – 2007 PSA reference level (Table 6). If this effort reduction is applied as a percentage scaling factor to the CTS PSA Susceptibility scores for each species: the number of high risk TEP species decreases by eight to zero; the number of high risk Bycatch species decreases by 96 with only three species remaining at high risk; and the number of high risk Byproduct species decreases by 35 with only four species remaining at high risk. In the GHaTS, fishing effort (number of sets) has decreased by 36% over the 2004 – 2007 PSA reference level. If this effort reduction is applied as a percentage scaling factor to the GHaTSPSA Susceptibility scores for each species: the number of high risk TEP species decreases by four with only two species remaining at high risk; the number of high risk Bycatch species decreases by two with only one species remaining at high risk; and the number of high risk Byproduct species decreases by five with six species remaining at high risk.

Figure 49 and Figure 50 show the results of applying effort changes to the 2012 SAFE *F* estimates for the CTS and GHaTS respectively (from Penney, 2016).

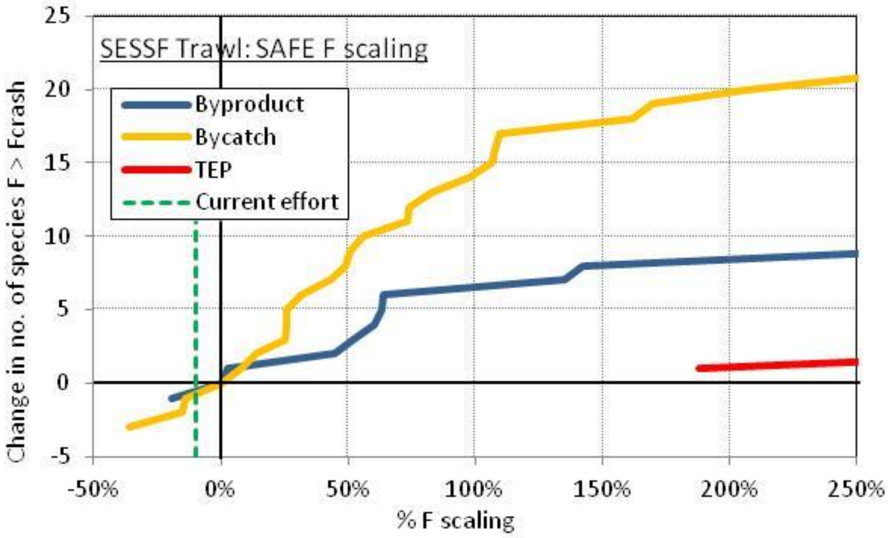


Figure 49. Increase or reduction in the number of species potentially at High risk in the CTS as fishing effort increases or decreases, with changes in effort applied as a percentage scaling factor to the SAFE *F* estimate (Penney, 2016). The current effort level as a percentage of the 2007 PSA reference effort level is shown by the green dashed line.

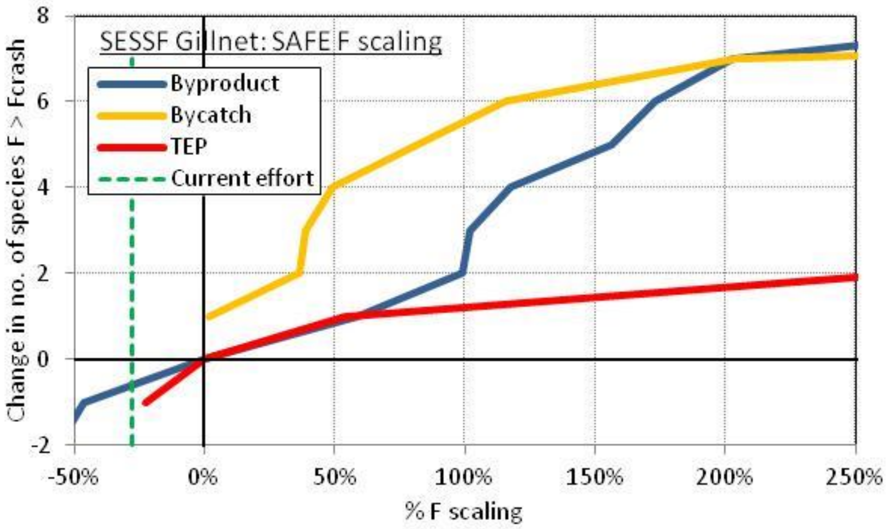


Figure 50. Increase or reduction in the number of species potentially at High risk in the GHaTS as fishing effort increases or decreases, with changes in effort applied as a percentage scaling factor to the SAFE *F* estimate (Penney, 2016). The current effort level as a percentage of the 2007 PSA reference effort level is shown by the green dashed line

In the CTS, fishing effort (number of trawl tows) has only decreased by 10% over the 2007 – 2010 SAFE reference level (7). If this effort reduction is applied as a percentage scaling factor to the CTS SAFE F estimates, there is no reduction in the number of high risk ($F > F_{crash}$) Bycatch or Byproduct species. The only high-risk Byproduct species would fall below high risk at a 19% effort decrease, and one high risk Bycatch species would fall below high risk at a 14% effort decrease, leaving two Bycatch species at high risk. There are no high risk TEP species in the CTS SAFE assessment, and would not be unless effort increased by 188%.

In the GHaTS, fishing effort (number of sets) has decreased by 28% over the 2007 – 2010 SAFE reference level (7). If this effort reduction is applied as a percentage scaling factor to the GHaTS SAFE *F* estimates, only high risk ($F > F_{crash}$) TEP species would drop below high risk. There would be no decrease in the number of high risk Byproduct species, although one high risk Bycatch species would fall below high risk at a 46% effort decrease leaving one Bycatch species at high risk. There are no high-risk Bycatch species identified from the GHaTS SAFE assessment, although one species would become high risk if effort increased by 2%.

At current effort levels, residual risk in the CTS and GHaTS is estimated to be similarly low under either PSA or SAFE assessments, with few species (seven to nine in PSA assessments, and three to four in SAFE assessments) assessed as potentially remaining at high risk. This reduced risk resulting directly from the reduction in fishing effort, and particularly when coupled with current TAC undercatch levels, provides strong justification for an increase in the period between assessments, or for a reduction in the mitigation requirements for these fisheries.

7.6. Vessel-level economic analysis

The aim of this section is to present a vessel-level economic analysis, and to consider the impact of changing assessment practices on the profits of individual vessels in the two key sectors in the fishery, the CTS and the GHaTS. The main results are presented below, with the methodology used to derive these presented at the end.

7.6.1. Baseline conditions

The analysis is largely based on economic survey data presented in Skirtun and Green (2015), for the 2012-13 financial year. In 2012-13, average vessel economic profits in the CTS were $109,000, with most vessels earning positive economic profits. In contrast, average economic profits in the GHaTS were -$25,900, with most boats experiencing economic losses. Economic profits take into account the opportunity cost of the owner-operator labour as well as capital, so are lower than financial profits (Figure 51).

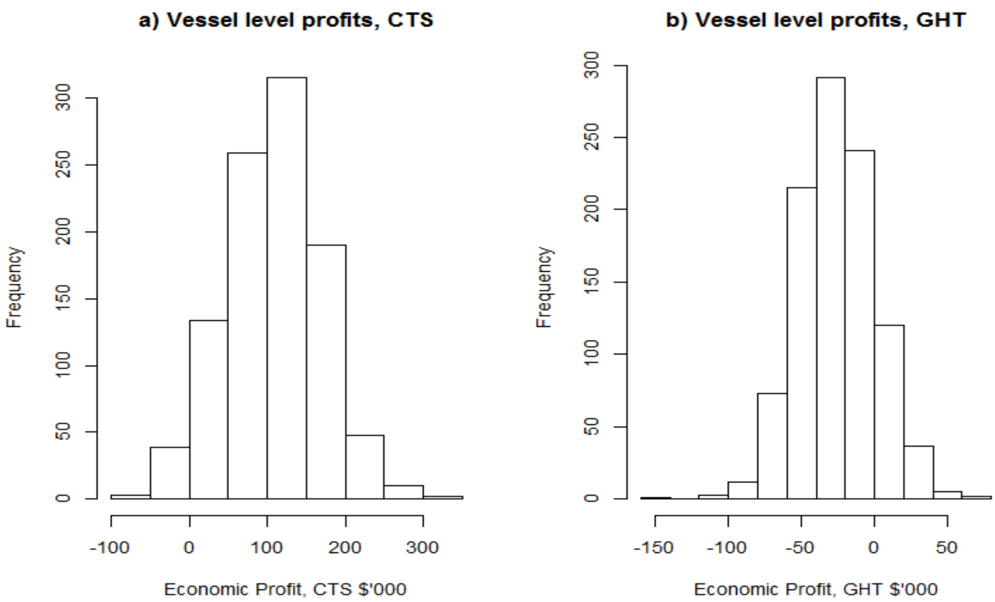


Figure 51. Vessel level profits in each sector.

Total fishery profits, derived from repeated sampling within the estimates of individual vessel profits, were estimated to be $5.4 million for the CTS and -$1.9 million for the GHaTS (Figure 52).

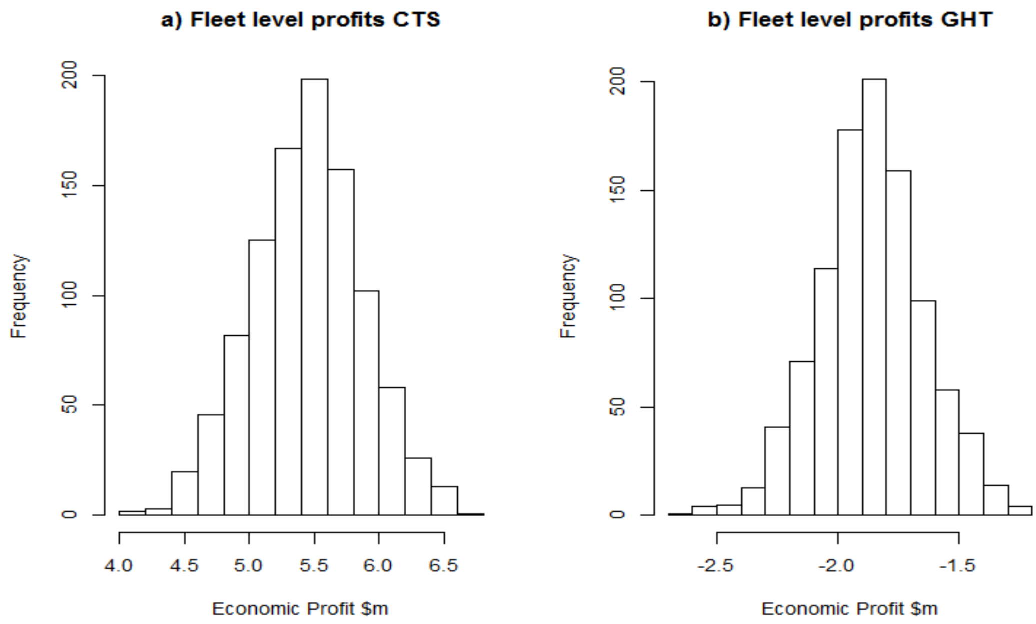


Figure 52. Total economics profits in each sector.

7.6.2. Management costs under each scenario

The current management costs, derived from the survey information, were about $5.5 million over both sectors, of which around $1.3 million was due to the data collection and assessment process (Table 19). The effects of changing the assessment tiers for the different species on assessment costs are also presented in (Table 32).

Table 32. Management costs, fishery level.

	Current total management costs ($m)	Assessment costs*				
		Current	All Tier1	All Tier 4	All Tier 5	Scenario1
CTS	2.95	1.06	1.55	0.53	0.42	0.76
GHT	2.53	0.28	0.43	0.15	0.12	0.25

* Excluding ERA and FIS costs, assumed constant at $157,000 and $645,000, respectively in all scenarios.

7.6.3. Impact on profits of alternative assessment and catch scenarios

7.6.3.1. Assuming the full 2015-16 quota is caught (all Tier 1)

If all vessels could catch the full recommended TAC, revenues of the CTS would more than double, while the GHaTS revenues would increase by about 24%. The impact of this on profits, once changes in variables costs have been taken into account, is shown in Figure 53 (CTS) and Figure 54 (GHaTS). For the CTS, average vessel profits are likely to increase by between $200k and $500k, with an average increase of around $380k.

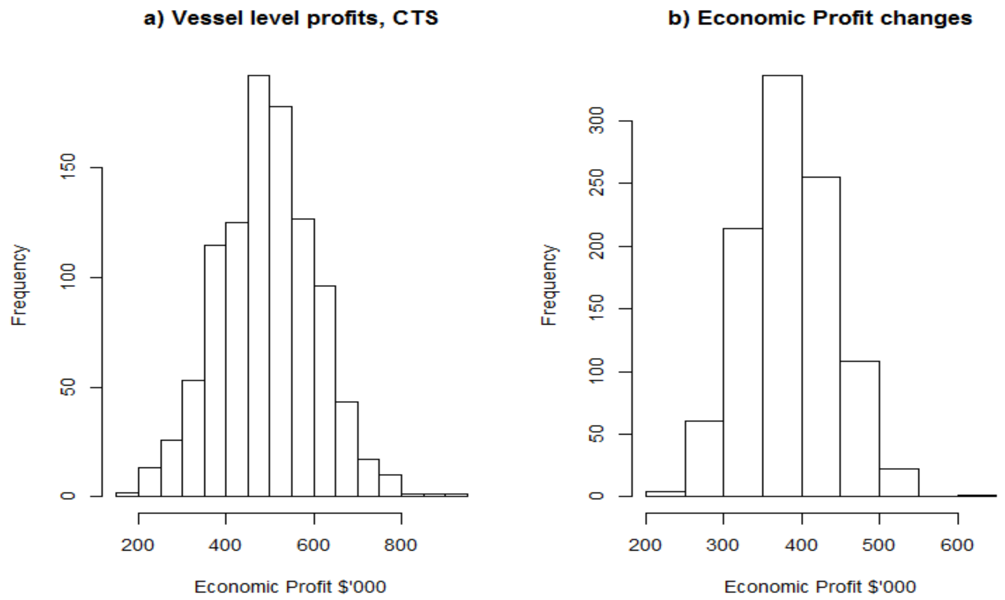


Figure 53. Impact on vessel profits, CTS.

For the GHaTS , if TACs were fully caught, vessel profits would increase by an average of around $31k, although about half of the fleet would still be earning negative economic profits (Figure 54).

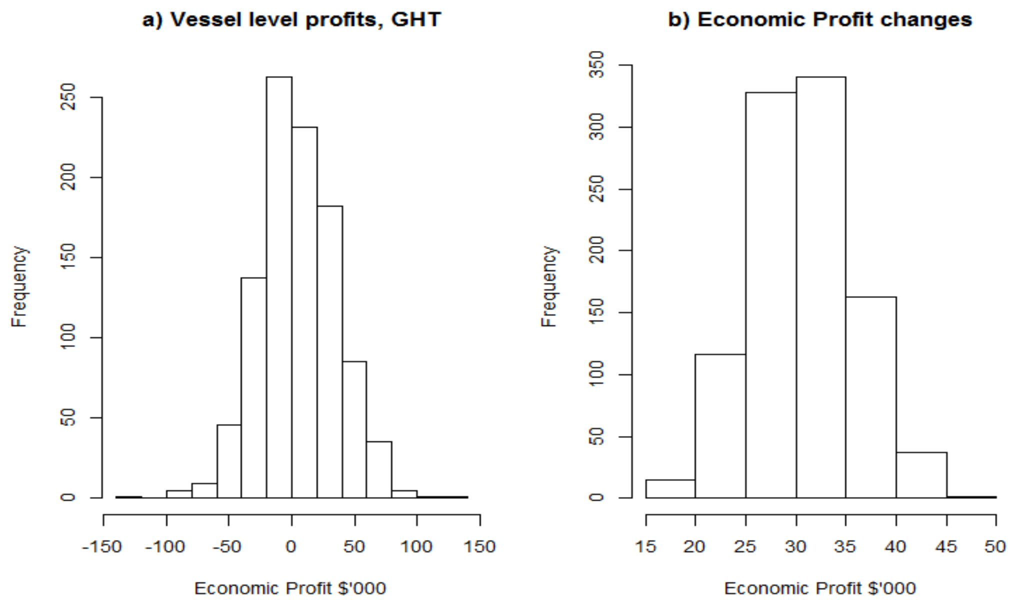


Figure 54. Impact on vessel profits, GHaTS.

These changes are a reflection of the increased revenues that would be associated with the higher catches, and are more indicative of the potential benefits to the fishery of catching the full TACs. Conversely, they represent the potential opportunity cost associated with the current undercatch levels. In some cases, it may be impractical to catch all species at their recommended biological catch levels due to issues around optimising multi-species catch and potentially incompatible quotas. Hence, the estimated increased profits represent a theoretical best-case outcome rather than what might be achieved in reality.

7.6.3.2. All species are assessed at Tier 4

Again, assuming that all catches can be taken, moving from all Tier 1 assessments to all Tier 4 assessments (given the assumed discount factor, of 15% for Tier 4 assessments) results in a loss in profits to vessels in both sectors (Figure 55) compared to the Tier 1 analysis. The CTS vessels incur the greatest opportunity cost, with an average of -$90k even after the lower assessment costs have been taken into account. The impact on the GHaTS is lower, with an average loss of -$21k.

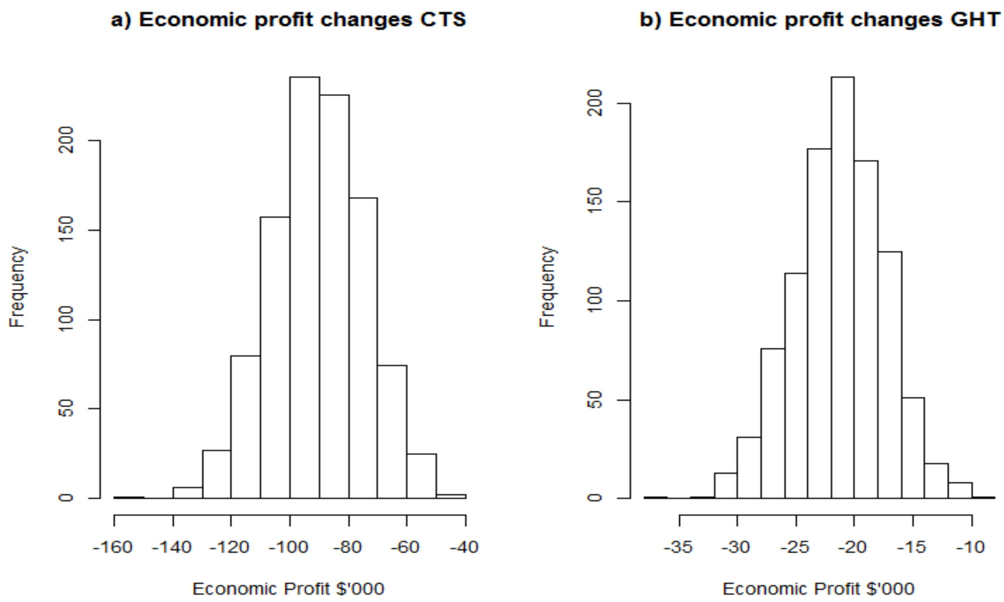


Figure 55.Impact on vessel profits of all Tier 4 assessments.

Average management costs saved at the vessel level from moving to all Tier 4 assessments are $4.4k and $1.5k for the CTS and GHaTS respectively, compared with current management costs. These savings are not sufficient to offset the large fall in revenue and profits resulting from lower catch limits. As for the Tier 1 analysis above, much of these profits would not accrue under the current undercatch levels, largely offsetting the lost opportunity costs.

7.6.3.3. All species are assessed at Tier 5

If all species were subject to Tier 5 assessments, catch targets would be only 75% of the Tier 1 equivalent TAC. Vessels in the CTS and GHaTS would each save $6.9k and $1.9k respectively through lower management costs. However, assuming that the full TACs are caught, average profits in these sectors would also decrease by around $164k and $38k respectively, even after the cost savings have been taken into consideration (Figure 56).

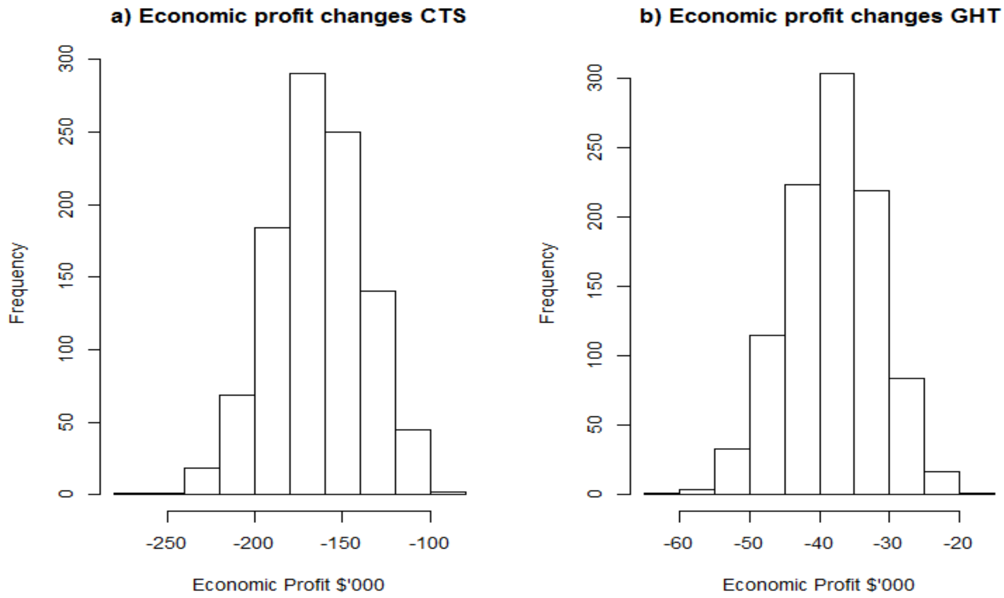


Figure 56. Impact on vessel profits of all Tier 5 assessments.

7.6.3.4. All species are assessed as per alternative scenario 1

Under the assessment strategy given by alternative assessment Scenario 1, vessels in the CTS and GHaTS would each save $6.1k and $0.4k respectively through lower management costs. However, average profits in these sectors would also decrease by around $44k and $4k respectively compared with the all Tier 1 scenario, even after the cost savings have been taken into consideration (Figure 57).

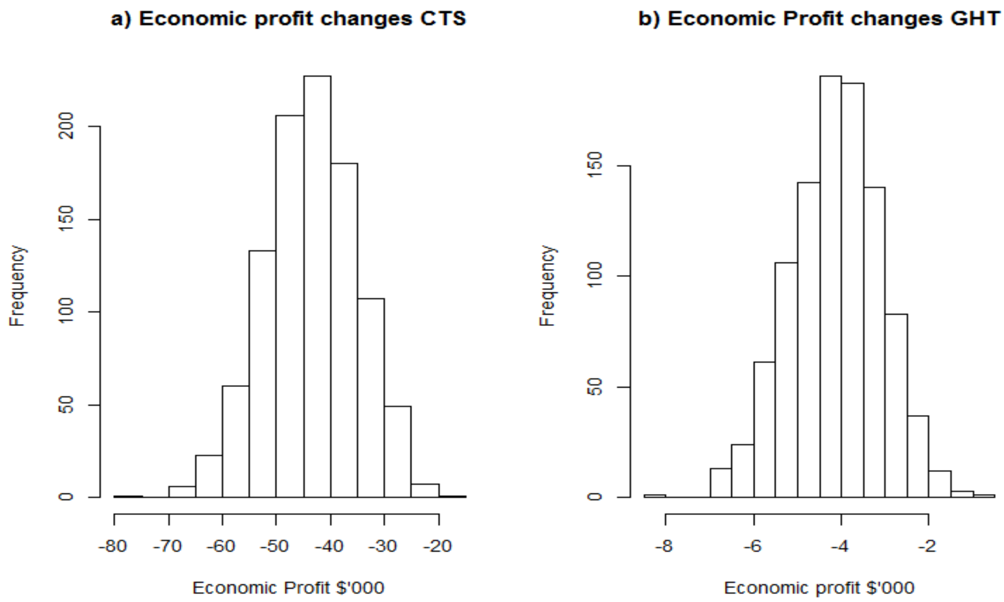


Figure 57. Impact on vessel profits of Scenario 1 assessments.

7.6.3.5. Effects of under-caught TACs

The above analyses were compared against an ideal scenario in which all the species were caught at the recommended TAC assuming a Tier 1 assessment for all main species. Accordingly, reducing the quality of the assessments results in a lower vessel profit on average, even taking into account the savings from the reduced monitoring and assessment costs.

However, current catches are below the TAC for all species, by varying degrees. Under a Scenario 1 assessment strategy, only one species would have a lower TAC than the current catch level (Ocean Perch offshore). This has only a minor impact on total CTS revenue (<1% reduction) and no impact on the GHaTS.

As noted above, cost savings under Scenario 1 compared with the current costs of management are relatively small – about $6.1k and $0.5k on a per vessel basis for the CTS and GHaTS respectively. The slight change in revenue due to the slightly lower catch of Ocean Perch results in a net gain to CTS vessels of between $3k and $5k, with an average of $4.1k (Figure 58). For the GHaTS, there was no change in revenue, so the gain was equal for all fishers (i.e. $0.5k).

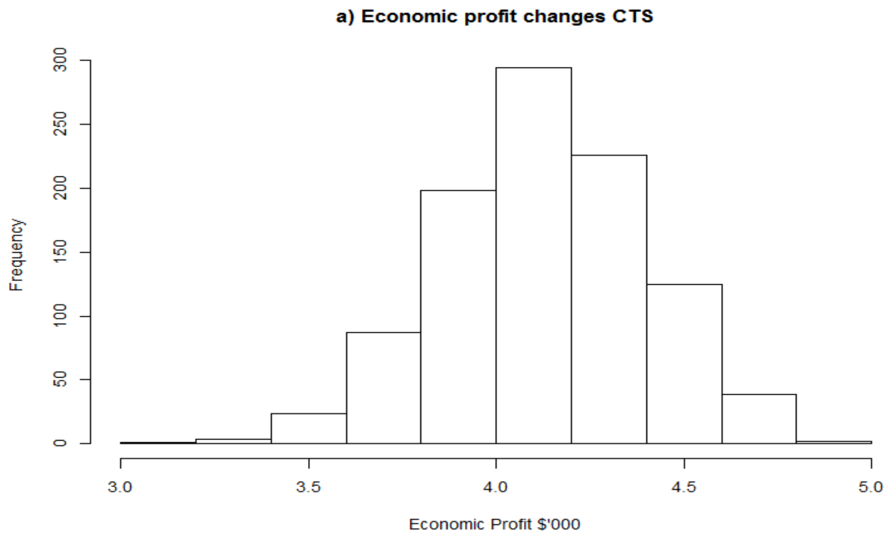


Figure 58. Impact on vessel profits of Scenario 1 assessments relative to current catches, CTS.

If Tier 4 assessments are applied to all species using current catches, the cost savings would be $4.4k and $1.5k for the CTS and GHaTS respectively, compared with current management costs. However, catches of several key species, and the resulting revenue, would be lower because the revised TACs would be less than the current catch (Figure 59).

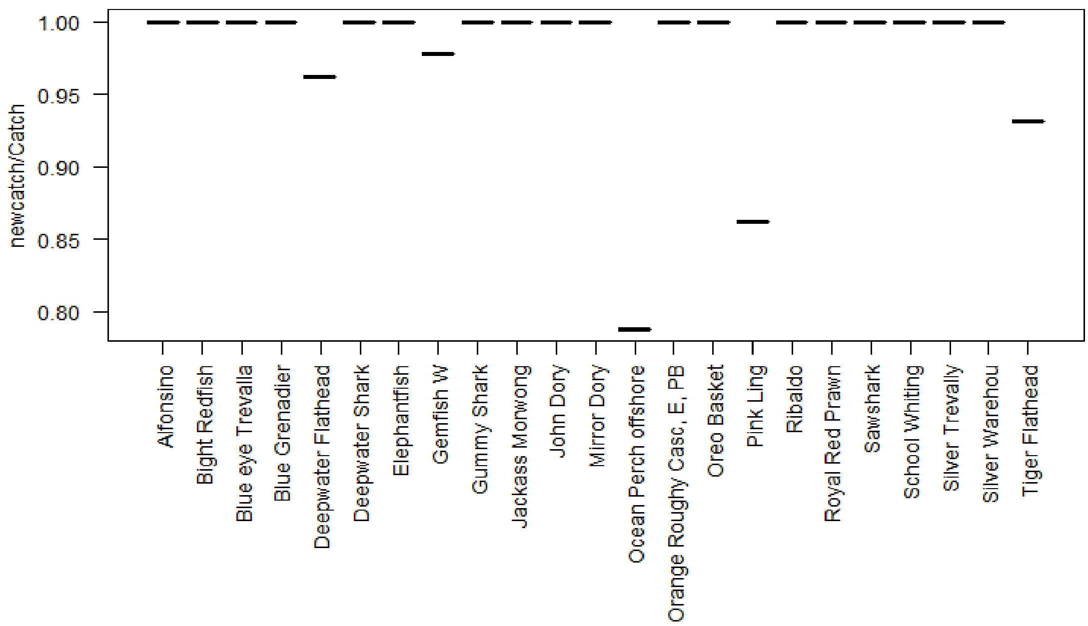


Figure 59. Comparison of current catches and potential catches per species under Tier 4 assessments (assuming that current catch is an upper bound), showing reduced catches for 5 species. Note: Y-axis starts at 0.8 rather than zero.

The net effect of application of Tier 4 assessments is to reduce vessel profits on average by about $1.6k for the CTS and $3.6k for the GHaTS vessels. For some CTS vessels, however, profits may increase by up to 4k, although decrease by as much as 8k for others (Figure 60). However, all vessels in the GHaTS would have overall lower economic profits as a result of moving to all-Tier 4 assessments.

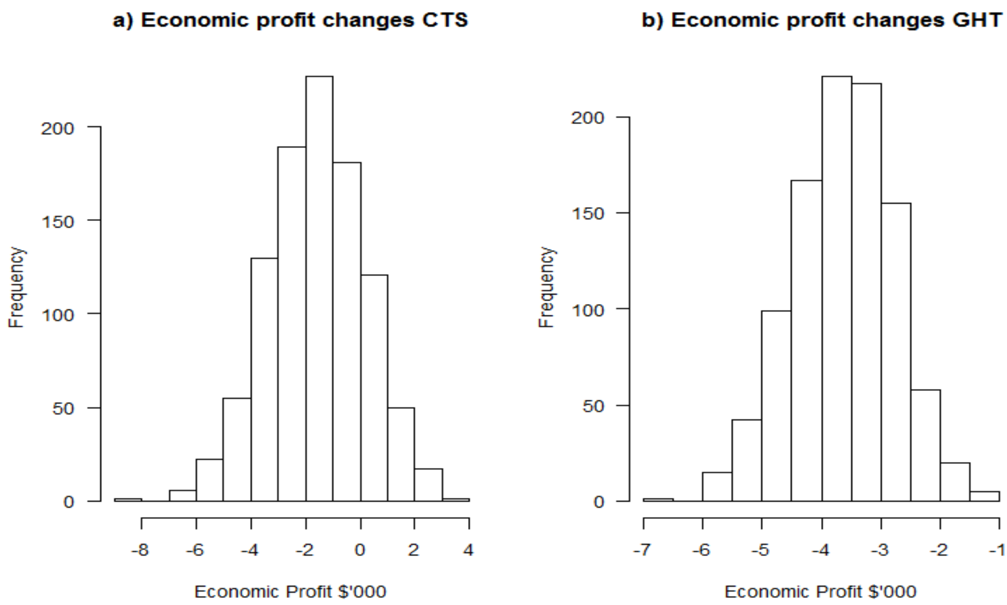


Figure 60. Impact on vessel profits of moving to all Tier 4 assessments relative to current catches.

7.6.4. Conclusions

A summary of the vessel level economic simulation analysis is given in Table 33. At the vessel level, cost savings by reducing the quality and frequency of the stock assessments are relatively small. In contrast, under the assumed discount factors for lower-information assessments, the increased use of lower information stock assessments will result in reduced total allowable catch reduced potential profits. Even compared with the current catch levels, lowering the assessments to Tier 4 (with a 15% discount on Tier 1 TACs) is likely to reduce, rather than increase, individual vessel profits, even after the cost savings have been taken into account.

Table 33. Summary of average changes in individual vessel profits under different scenarios

	CTS	GHaTS
Full TACs caught		
• Tier 1 (compared with current)	$380,000	$31,000
• Tier 4 (compared with T1)	-$90,000	-$21,000
• Tier 5 (compared with T1)	-$164,000	-$38,000
• Option 1 (compared with T1)	-$44,000	-$4,000
Actual catches		
• Option 1 (compared with current)	$4,100	$480
• Tier 4 (compared with current)	-$1,600	-$3,600

Rather than reducing stock assessment Tiers, greater benefits may be realised by establishing why the current total allowable catches are not being achieved. Substantial gains could be achieved if catches could be taken at their recommended catch levels, even with higher assessment costs. It is possible that TACs are overestimated as they are produced through single species stock assessments rather than taking into consideration the mixed fishery nature of the fishing activity. A multispecies/mixed fishery stock assessment may result in lower TACS and less underutilised quota, although such assessments are complex, time consuming, expensive and adequate data may not be available to provide robust results. However, in such a case, introducing lower tiered assessment and monitoring systems may result in even lower TACs being introduced, placing greater pressure on existing profits, although this needs to be MSE tested. There is considerable merit in determining why TACs are being under-caught, and the implications of alternative TAC-setting approaches for both costs and fishery profit.

8. Results and Discussion - Objective 4

8.1. A review of research, monitoring and assessment approaches in North America, South Africa, Canada and New Zealand, focusing on cost effectiveness.

The review of research, monitoring and assessment approaches in North America, South Africa, Canada and New Zealand, focusing on cost effectiveness (Bergh 2016) is presented in full in Appendix 7c, key points from which are summarised below.

8.1.1. United States

There is increasing interest in the use of electronic tracking, monitoring, and reporting technologies in the USA because they offer the potential to improve the quality of data collected for compliance, science and management, and reduce data collection costs. Studies in the USA of the use of electronic monitoring (EM) have shown some issues with reliability, however some fisheries lend themselves to cost effective EM for specific types of data collection (e.g. the midwater trawl herring/mackerel fishery). As of 2013, there were no operational video monitoring programs in NMFS-managed fisheries where data extracted from video are used for science or management purposes, however more recently, regional electronic reporting (ER) / EM implementation plans have been published, and numerous trials have been conducted.

For the USA, potentially more than 1000 stocks require assessment. However, given the impracticability of achieving this on an annual basis, in 2005, the Fish Stock Sustainability Index (FSSI) was created and the 230 stocks included in this index effectively became “core” stocks. FSSI stocks contribute 90% of the fish catch. In 2014, NOAA recommended a regional application of the stock assessment prioritization process, and not a fully national level application. This process can be divided into two parts: First, the determination of the Stock Assessment Improvement Plan (SAIP) level (similar to the SESSF’s Tier levels) and the appropriate frequency. Secondly, prioritization of the distribution of stock assessment resources amongst stocks.

There is growing interest in applying the management strategy evaluation (MSE) approach in the USA. However, there are very few examples of using a MSE framework to evaluate a realistically implementable management procedure (MP) for fishery rebuilding. There are a number of factors which inhibit the use of MSE and MPs. As in most countries, fisheries managers typically lack the resources to undertake an MSE in addition to the normal data collection and stock assessment process. Furthermore, most fisheries in the USA do not have commercial stakeholder organizations that can legitimately represent the interests of the overall commercial fishery and agree on a particular MP. This is important because a lack of agreement on the MP could lead to political pressure to abandon the procedure if it leads to greater TAC reductions or to slower increases than desired by some groups.

THE USA has been progressing towards EBFM for more than a decade. There is also a well-developed set of regulations and procedures for monitoring and minimizing the impact of fishing on protected bycatch species. These regulations and procedures include observer programs, training, spatial and temporal restrictions, gear modification, and other mitigation measures.

8.1.2. New Zealand

The Minister of Fisheries is responsible for administering New Zealand’s *Fisheries Management* Act 1996. This is done through “outputs” which can be grouped into six headings:

- Policy Framework
- Fisheries Information and Management
- Regulatory Management

- Fisheries Access and Administration
- Enforcement of Fisheries Policies
- Prosecution of Offences

Some of these outputs are outsourced including a large proportion of stock assessment and biodiversity research. The setting of management measures and decisions on the level and extent of the Ministry’s fisheries services are subject to consultation with fisheries stakeholders (commercial, customary Maori, recreational, environmental), which occurs as a matter of good administrative practice, and for many decisions is required by the Act.

Of the 636 fish stocks on the NZ management system, 288 are considered to be “nominal” or “administrative” stocks (species-area combinations for which the TAC is 0–20 t, or where a significant commercial or non-commercial potential has not been demonstrated). For the remaining 348 stocks, 77% of which have been in the Quota Management System (QMS) for 10–27 years, TACs for 57% have never been altered and there have been two or fewer changes for 89% of stocks. Only 16 of the 348 stocks have experienced five or more changes in TAC. The main reason for this is the paucity of research and assessment information to inform quota changes, particularly for small or unimportant stocks. Therefore, implicit constant catch scenarios are actually the norm and the legacy of the initial design of the system prevails. However, for some key species, alternative approaches have been taken, including setting TACs based on projections of stock size under alternative TAC scenarios (e.g. Hoki) or developing management strategy evaluations (e.g. rock lobster). In these cases, alternative scenarios are scientifically evaluated using performance measures related to the probability of stocks attaining management targets or falling below biomass limits.

New Zealand has a long history of taking steps towards reducing interactions with protected species. Steps to reduce interactions with seabirds began more than 25 years ago, and the National Plan of Action (NPOA-seabirds) covering all New Zealand fisheries was published in 2004 and recently revised. Sea lion exclusion devices have been in use in trawl fisheries for squid to reduce captures of New Zealand sea lions since ~2000, and various area closures have been introduced to reduce captures of Hector's and Maui's dolphins in coastal trawl and set-net fisheries. Monitoring of interactions is guided by increasingly comprehensive semi-quantitative risk assessments, which estimate potential annual fatalities relative to potential biological removals. Fully quantitative population modelling to assess risks posed by fishing have also been conducted for about six seabird species and two marine mammals.

When the QMS was introduced in 1986, it was presumed that fish bycatch would be dealt with through the need to have access to quota for all species of commercial importance, which is one reason most are now included in the QMS. Total bycatch and discards are monitored for key offshore trawl and longline fisheries using observer and fisher-reported catch-effort information. However, inshore fisheries have had low observer coverage and it has not been possible to assess levels of bycatch and discarding quantitatively in these fisheries. It has also been difficult to estimate unrecorded fishing-related mortality of non-QMS fish at a species level. In recognition of the effects on biodiversity and fish nursery areas, certain coastal areas with particularly dense emergent invertebrates (known to be particularly susceptible to fishing disturbance) were closed to bottom trawling and dredging in the 1990s.

There is growing interest from the Ministry for Primary Industries (MPI) and other fisheries stakeholders in methods to assess New Zealand fish stocks with low levels of data. However, while some preliminary work has been done in New Zealand, a formal decision making process around data poor stocks and the approaches that should be followed are unavailable.

At least one EM trial has been undertaken in New Zealand focussing on protected species interactions, observations, and mitigation measures. Imagery collected was mostly usable. However, there were a range of issues including a lack of a complete record of fishing trips, image quality, poor image quality during night operations because of lack of light, and selection of camera location for optimal results is problematic.

8.1.3. Canada

Canada is pursuing and intensifying a cost-recovery program for the provision of fisheries services, including absorbing full costs of the At-Sea Observer Program nationally, as well as the Groundfish Electronic Monitoring Program in the Pacific Region. Canada's At-Sea Observer Program places certified private-sector observers aboard fishing vessels to monitor fishing activities; collect scientific data; and monitor industry compliance with fishing regulations and licence conditions. The Fisheries and Oceans Canada (DFO) now has standards in place to designate individual at-sea observers and corporations seeking to provide at-sea observer services. The Pacific Region's Groundfish Electronic Monitoring Program uses multiple cameras and sensory devices onboard fishing vessels to monitor fishing activities, collect scientific data, and monitor industry compliance with fishing regulations and licence conditions.

Fisheries and Oceans Canada are developing a new DFO Standard on electronic logbook client applications, and will be responsible for validating E-log client applications developed externally. On January 1, 2013, fish harvesters across Canada took responsibility for obtaining their own Logbooks and/or Combined Forms. While DFO was able to provide its remaining inventory of logbooks to many participants in the 2013 fishing season, fish harvesters must now acquire these documents from a supplier.

8.1.4. South Africa

The Department of Agriculture, Forestry and Fisheries (DAFF) is responsible for marine resources management under the *Marine Living Resources* Act 1998 (MLRA). Scientific advice on fisheries management is coordinated through the Scientific Working Groups (SWGs), which are bodies appointed by DAFF and the meetings of which are convened and coordinated by DAFF. The SWGs typically comprise DAFF employees, but DAFF's main scientific consultants are also members on a number of the SWGs. Fishing Industry Associations attend the SWGs as observers. NGOs such as Coastal Links, BirdLife South Africa, Traffic, or WWF also attend as observers. The chairperson of the SWG drafts the SWGs recommendations and submits these to the Director of Research. The Director of Research does not have the power to change these recommendations so the SWG recommendations generally apply. The Director of Research then sends the recommendation up to the Deputy Director General (DDG) for Fisheries. It is very rare for the Minister's or his/her delegated authority to deviate from the scientific recommendation. Another bodies involved in the decision-making process are Management Working Groups (MWGs). These groups meet far less frequently but are intended to provide socio-economic and other input not available to the SWGs (which deal with scientific matters).

South Africa employs a range of data collection programs including fishery-dependent catch weight, effort, and biological (including length and age) data via logbooks, fisheries observers and VMS, and fisheries-independent hydroacoustic abundance surveys, spawner biomass and recruitment surveys, annual trawl surveys, daily egg production method (DEPM), and parasitology.

Operational management procedures (OMPs) are used to manage some of the main fisheries. OMPs are analogous to an MSE approach, and examine the implications of changes to "fisheries services" (mainly reductions in research services) and sustainable catches that can be derived from the resource on an equivalent risk basis. This requires that the measure of biological risk is defined mathematically, and then the calculation of the forfeited catch implied by a reduction in "research services" can be calculated.

South Africa is committed to developing and implementing an Ecosystem Approach to Fisheries (EAF) management. EAF is based on two main principles. The first relates to maintaining and enhancing the ecosystem health as a whole and the second refers to balancing diverse societal needs and values. Ten EAFs have been conducted in southern Africa: six in South Africa and four in Namibia. Methods used were adapted for local use from those developed by Fletcher *et al.* (2002). Despite the initiatives documented above, EAF remains a controversial topic for local fisheries management. Detractors are point out that EAF has had little impact on real fisheries management decisions anywhere in the world whereas proponents note global support for EAF suggesting inevitable adoption.

The Demersal Working Group regularly discusses and updates priorities for stock assessment work, but there is no formal procedure or scoring system that is used for the development of these priorities. The following general workplan applies to stock assessments in South Africa:

For stocks which are managed by OMPs, detailed and frequently substantially-revised stock assessments are conducted every four years during the revision of OMPs. This revision process involves a period of work and research of typically (for hakes) 18 months, during which substantive new stock assessment work is conducted.

In all years, for hakes, the most recent stock assessment model is run with updated data as available.

For retained and important bycatch species in the offshore trawl sector, detailed stock assessments are run far less frequently. In some cases, shortcut methods are employed - the most common technique has been the replacement yield approach using catch rate and/or demersal abundance indices as inputs (in addition to annual catches).

With the exception of the squid jigging fishery in the Eastern Cape, most fisheries in South Africa are managed by means of output controls, either by means of explicit TACs and individual quotas, or in the case of by-catch in the hake trawl fishery, by a PUCL (Precautionary Upper Catch Limit). However, the industry (with government support) has initiated input controls, specifically effort controls, in the South Coast rock lobster fishery and in the hake trawl fishery, and is busy formulating proposals for effort controls for the West Coast rock lobster fishery.

8.1.5. Synthesis and recommendations for research, monitoring and assessment

- The international review has sourced a diversity, but not an exhaustive set, of available information about the practices and developments in the provision of fisheries services for research, monitoring and assessment, in the USA, Canada, South Africa and New Zealand.
- The most expensive aspects of fisheries services, excluding monitoring, control and surveillance (MCS) and enforcement, are at-sea observer programmes, fishery-independent surveys and stock assessments combined with the formulation of management approaches and management advice, as well as growing public pressure for ecologically sustainable fisheries management.
- The ecosystem approach to fisheries is leading to an increase in the scope of fisheries services, particularly in multispecies trawl and long-line fisheries.

8.1.5.1. Stock assessments and management services - towards cost efficiencies

The USA has more than 400 species and/or fish stocks under management, and New Zealand more than 600. All fish stocks are potentially separate entities that have a need for fisheries services. All stocks may, in terms of existing legislation, require the determination of TACs and eventually ITQs (New Zealand) or catch shares (USA). In New Zealand many stocks have TACs that remain unchanged over many years. Explicit attention, including fisheries services, is on the most valuable stocks. In the USA a much more explicit prioritisation of fisheries services for stock assessment takes place. Available resources for stock assessments are allocated in the most "profitable" manner, and once allocated are likely to avoid wasteful application of stock assessment expertise. In particular, this framework allows for the designation of resources for a first-time assessment. This resource allocation approach has merit, particularly if there is widespread stakeholder involvement in its development and adoption.

Decisions relating to resource allocation, including the timing and prioritisation of stock assessments are transparent, saving considerable time in planning and administration. NOAA has recommended that this system be applied at a regional level in the USA.

Although not a topic reviewed here, a number of RFMOs (IOTC, WCPFC, CCAMLLR) are pursuing "canned" stock assessments based on the application of easy to use fisheries software packages such as Stock Synthesis, Multifan, Casal and others. These packages offer a less expensive route to performing age-structured stock assessments compared with approaches where stock assessment models are individually coded using programming templates like ADMB and TMB. Such options should be explored since these canned approaches do offer the capability to include a variety of data types typical of many fisheries. The assessments can be implemented by persons who are not computer coding experts or stock assessment experts, but they may be fisheries biologists who have an aptitude for stock assessment. This would be an option for data moderate to data rich fisheries that do not number above 10 or 20 stocks. It would also require, for a given stock assessment, the development of appropriate management advice. The "canned" systems may provide sufficient functionality for this.

A different approach should be used for those data-poor fisheries that form most fish stocks. In such cases the best approaches, consistent with the best international advice and precedent, are shortcut methods which provide a direct management recommendation, i.e. empirical management procedures, without an intervening stock assessment analysis, which have been validated by use of the MSE approach. Even though MPs consistent with the IWC definition are non-existent in the USA context, and only one instance is on record for New Zealand, application of shortcut methods is well established in South Africa. There is a distinction between MSE / MPs for data-rich versus data-poor fisheries, suggesting that the expenditure of resources in developing new MPs and / or refining existing MPs (as in e.g. Knuckey *et al.*, 2008) for data-poor fisheries is worth pursuing further. At least two options may be considered. One is to develop MPs that are applicable to a basket of species or stocks that share common biological and data characteristics (the "basket" approach), thereby achieving an economy of scale with respect to the expenditure of technical expertise. The second is to develop "canned" MSE / MP systems which can quickly update MPs for a specific data-poor stock, from which hundreds of MPs could be developed with relatively little expense.

There is one reservation about the "basket" approach. In the above, stock assessment services are a cost, and cost reductions are under consideration. However, the terms of reference of this project are *inter alia* to examine cost efficiencies in relation to the intensity and frequency of fisheries and research services. Thus, there is a requirement that, in making recommendations about fisheries service provision, the capability to give advice about trade-offs between fisheries service costs / fisheries management risk / fisheries sustainability is developed. Only the MSE / MP approach has the potential to provide this capability because the empirical approaches that have been reviewed have not been successful and, elsewhere in the world (South Africa for example), MSE / MP is the dominant approach for exploring such trade-offs. Therefore, given to continuing concerns about the costs of fisheries services, the MSE / MP approach would be able to compare the merits of different survey frequencies and other aspects of fisheries services. Whether the "basket" approach is flexible enough to allow such cost-benefit analysis or whether the "canned MSE" approach is better depends on whether the trade-off issue needs regular review (every year) or less frequently (every 5 to 10 years).

8.1.5.2. Fisheries independent surveys

All available literature emphasizes the importance and value of a time series of fisheries independent surveys. The examples from the USA reveal planning at a federal level to estimate the quantity of surveys needed, the best design for the Fisheries Research Vessels (FRVs) required to meet these requirements, and the recognition of the need for a degree of chartered vessel and university vessel input to complement the FRV capability. The cost benefits of different levels of FIS frequency are not clearly expressed in the USA, although FIS seem to be conducted at least annually for important stocks.

The examples from South Africa reveal the value of the MSE / MP approach in conducting cost benefit analysis of FIS.

In the USA, the investment in FIS capability is substantial. NOAA supplements the use of dedicated FRVs with charters (about 50% of requirements). Charters include the use of commercial vessels and other research vessels. Commercial charters are particularly useful when specific vessel configurations (e.g. gear types) are not required in contrast to dedicated vessels such as trawlers (important in trawl surveys). The use of commercial charters for trawl surveys requires allied research to cross calibrate different vessels. These calibration surveys are relatively expensive so any use of commercial charters for trawl must weigh up either the costs of these calibration surveys, or the cost to the fishery of the additional risk aversion required to incorporate uncertain cross calibration factors among charter vessels. An ideal situation might be where a commercial charter is available over many years, nullifying the calibration problem.

For trawl fisheries, there is the temptation to dispense with fisheries independent surveys, and rely solely on CPUE data. However, trawl technology is constantly improving adding a source of variation to CPUE. Costs savings for FIS therefore need to consider, amongst other possible measures:

- Minimizing where possible the frequency of surveys
- The multi-functional application of FRVs.

Recommended frequency of surveys:

This review did not find a basis for providing generic advice on the recommended frequency of surveys. Notably, the methods for the prioritization of stock assessments in the USA include proposals to link the frequency of stock assessments to the average age of fish in the exploited stock, modified by the amount of recruitment variability - decreasing the interval by a specific amount for stocks with high levels of recruitment variability, or increasing them by a specified amount for stocks with low variability. This link between productivity and assessment frequency has application to the cost benefits of FIS. This could be validated using an MSE / MP approach and a decision rule based on this could be a useful tool for planning fisheries independent surveys.

8.1.5.3. Electronic Monitoring

Monitoring by means of at-sea observers is expensive. For almost ten years video based monitoring, or EM (Electronic monitoring) has been trialled in the USA, Canada, Australia and New Zealand. Studies have assessed the efficacy of this technology according to the same standards that at-sea observers are measured. The results are equivocal and case and issue specific. Most studies conclude that EM is less expensive than using at-sea observers.

Most studies report that the EM performs well as a compliance monitoring tool, but poorly at estimating discards and interactions with TEP species, or for gathering data that can be used in science and management. Some studies favour the use of EM technology as a means of auditing the reliability of self-sampling work. A New Zealand study concluded that the review work involved in assessment of EM could be done on shore such that experts in local fauna could be enlisted to increase the reliability and detail of species identification achieved. The adoption of the present generation of EM technology in science and management in North America is extremely limited, non-existent in New Zealand and much of the available information relates to pilot studies conducted to assess the usefulness of the technology.

Yet technology is rapidly evolving and the limitations discussed above may soon be overcome. These include systems based on high or variable frequency high definition camera stills instead of video and they may offer a number of advantages in particular situations. Advances in artificial intelligence may also lead to automated analysis.

8.1.6. Electronic Reporting

Electronic Reporting (ER) offers cost savings compared with the regular paper logbook approach, and the uptake of this technology is widespread in certain countries and jurisdictions (for example the EU and Australia, but not to the same extent in the USA). Apart from cost savings, an advantage of ER is the ability to access a far greater range of data than is feasible using paper logbooks, potentially providing access to "big data". Furthermore, the more sophisticated offerings go beyond simple ER and include a shipboard data centre which allows skippers and crew to accumulate all fishing data over time and use the data with the help of historical reports, GIS views and other facilities, offering a service which the vessel skipper can use to achieve efficiency enhancements. This is an incentive which motivates further adoption of ER with cost savings.

Accordingly, the adoption of ER is strongly recommended. It is demonstrably cost-effective to source commercial products which suppliers can customize for purpose. However, it is also recommended that the central authority (e.g. AFMA) issues data standards and certifies suppliers' products as being consistent with these standards.

8.1.7. Ecosystem approach to fisheries

It is clear that fisheries management authorities in all jurisdictions relevant to this review have been tasked with adopting an ecosystem approach to fisheries management, EAF, consistent with the undertakings that their governments have made at international level. However, it is far less clear what EAF means in operational terms.

An EAF has the potential to make considerable demands on fisheries services with concomitant increases in costs (usually passed onto the commercial sector). Traditionally, research and management agencies have taken a single species approach to fish stocks and their management. Fisheries science dealing with monitoring and assessing single species involves considerable uncertainty, an ecosystem approach very much more.

In South Africa, the EAF approach has progressed such that ERA's (ecological risk assessments) have been carried out for the major fisheries, using a method adapted from Fletcher *et al.* (2002). These ERA's represent an inventory of the scope of issues that need to be considered with respect to governance, sustainability of fisheries, and broader environmental and ecological impacts. In some cases, they also touch on socio-economic aspects. Moreover, some specific ecosystem-level models have been developed. However, none have any demonstrable impact on fisheries management. Even so, emerging societal expectations and ecosystem-based certification systems (e.g. MSC) will ensure that EAF remains a priority for fisheries management.

In the USA the incorporation of EAF or EBFM (Ecosystem Based Fisheries Management) into FMPs (Fisheries Management Plans) was initiated by a policy and action framework summarized in Fluharty and Cyr (2001). A NOAA (2014) assessment of progress against those actions by each of the eight regional fisheries management councils shows only partial compliance with these actions. Even so, significant progress has been made. The USA approach provides a useful example of the application of EAF and how to assess progress. This could be compared with the Australian approach to see what gaps if any exist, and what could be usefully applied in Australia.

8.1.8. Other recommendations

8.1.8.1. Dual Input / Output Controls

Dual input / output controls are considered in the context of South Africa's experience. In the way that these have been developed and implemented:

- The input controls are intended to complement and not replace the existing and traditional output controls based on TACs, ITQs and PUCLs.

- Input controls are a secondary control measure, designed so that they will typically become an active constraint in 1 in 20 years only.
- Input controls have been initiated by the industry and have therefore been designed on a consensus basis.
- Input controls are allocated to fishing rights holders as, for example, seadays pro rata to their ITQ (catch share),
- they have led to very positive outcomes. Such controls are also consistent with FAO's code of conduct for responsible fisheries management.

There may be opportunities for dual input / output controls in the SESSF, and in conjunction with an MSE / MP approach to management they could favourably alter the cost - risk - benefit frontier, and should be considered for implementation, where such benefits are evident or demonstrated by MSE research.

8.1.8.2. Streamlining procurement processes for fisheries services

Examples from New Zealand demonstrate advantages in the alignment of fisheries services with the objectives of FMPs, and to streamline the process management by which fisheries services are procured. In large commercial operations, improvements in Business Process Management (BPM), if properly planned and implemented, are normally associated with large cost savings and efficiency improvements.

9. Results and Discussion - Objective 5

9.1. Improvement in monitoring and assessment arrangements for the SESSF fishery

A second Reference Group workshop was held at CSIRO, Hobart in June 2016 to provide feedback to key stakeholders on the results of the project to date, and to provide stakeholders with an opportunity to discuss and make recommendations for improvements to SESSF monitoring and assessment. The full report of the workshop is attached in Appendix 4: Report of the 2nd Reference Group Consultation Workshop.

The purposes of the workshop were to:

- To present the results of cost evaluations of alternative monitoring and assessment scenarios.
- To identify risk trade-offs under alternative scenarios.
- To identify viable future options for an effective balance of monitoring and assessment options.

Members of the project team gave presentations summarising the key project results relating to:

- Species categorisation, targets and default assessments.
- Alternative monitoring and assessment scenarios - costs and trade-offs
    - Alternative scenarios
    - Scheduling of assessments
    - Lost opportunity costs
- Vessel level economic analysis.
- Risk and information trade-offs.

9.1.1. Overview of 2nd Workshop recommendations

Following discussion of the project results, three breakout groups were formed to develop recommendations to address what the main issues identified by the participants. While there were differences in the emphasis and balance of recommendations made by the three breakout groups, the three groups covered most of the recommendations, or at least posed questions about such recommendations, on all the key issues of concern raised by participants at the 1st reference group workshop (as documented in Appendix 3: Report of the 1st Reference Group Consultation Workshop). There were notable similarities in recommendations by the three breakout groups on a number of aspects of monitoring and assessment, suggesting these to be the most important. The summary below attempts to synthesise the most important or common elements in the recommendations of the three groups.

<u>Monitoring</u>:

- Logbooks are considered to be the most important data source for primary and secondary species. Reliability of these data needs to be improved, and records should move towards E-logs, supplemented by other electronic monitoring systems. E-monitoring should be considered as a tool for validation of logbooks.
- Duplicate data collection must be avoided. Where data are collected in multiple ways, these need to be rationalised or integrated into an efficient system.
- Efforts are required to optimise the efficiency of data validation, extraction and transfer between AFMA and researchers, to minimise assessment time and costs relating to data preparation.

- Length-frequency data collected by ISMP, FIS surveys and industry need to be rationalised and integrated. All length-frequency data need to be captured into AFMA databases in compatible formats, so that they can be efficiently extracted, combined and used in analyses.
- Coverage of byproduct and bycatch discards, and of TEP interactions, needs to be improved. Observers may remain the best way to collect detailed data. E-monitoring may be an option for monitoring interactions with certain TEP species.
- There remain questions or concerns about the cost-effectiveness of high-cost monitoring activities such as the FIS.

Assessment:

- Management strategy evaluation needs to be used to determine optimal or acceptable frequencies for stocks assessments and for certain data preparation components, such as ageing.
- Infrequent assessments, or deferral of assessments until some trigger is breached, may be efficient for species with reliable assessments and under-caught TACs.
- Buffers or discount factors are required between different assessment tiers, and need to relate to the relative certainty of estimates of *B* and *F* at different tiers.
- ERAs should remain the main assessment tool for both byproduct and bycatch species, with both being managed to have a low risk of breaching a limit reference point analogous to the limit reference point under the Harvest Strategy Policy.
- Additional information or assurance is required that ERAs do measure risk analogous to that of breaching a limit reference point.
- Assessment of population status, effectiveness of mitigation measures, and cumulative impact of fisheries on TEP species, requires separate dedicated research projects.

General:

- Better understanding is needed of the reasons for TAC undercatch. A separate research project should address question such as: Are there any concerns relating to using single-species assessments in a multi-species fishery? Are there effects of climate change or other productivity changes that are not captured by current assessments? Are there operational constraints on catching TACs that could be reduced to improve fishery economic performance?

9.2. Options for efficiency gains

Following consideration of the recommendations from the reference group workshop, the project team identified a number of additional questions that should be asked in relation to current monitoring and assessments arrangements, as well as a number of associated options for efficiency gains.

9.2.1. Timing of data collection, assessment and reporting

- The rate of change of fishery characteristics (bycatch / discarding / TEP interactions / benthic footprint / economic data etc.) should be evaluated and assessed against the spatial / temporal resolution of data collection, assessment and reporting requirements to determine the most efficient data collection resolution to suit assessments.
- Data collected should be reported annually, but the frequency of full analysis and reporting could be reduced.
- What are the implications of running the observer program intermittently, such as only in alternate years?

9.2.2. Matching data collection to data requirements

- Are we collecting more/less data than we need (including spatial and temporal considerations)?

- Have we never used some of the data collected in a quantitative assessment? Could we stop collecting these data, or alternately could they be used in assessments?
- Alternative data collection methods such as EM, genetic data and eLogs, should be evaluated and implemented.
- Are there economies of scale to be achieved through broader scale rollout of alternative stock assessment methods? E.g. collecting genetic samples for close kin studies through port sampling.

9.2.3. Improved integration of data collection between programs

- How can we achieve better integration of length frequency data and otoliths collected by observers, industry and the FIS?

9.2.4. Application of different assessment techniques

- Do we need to run same assessment type each year, or could lower information assessments be adequate for monitoring of breakout rules in intervening years?
- Can risk assessments be used more broadly or efficiently, or could risk assessments replace stock assessments for low risk / undercaught stocks? ERA results be integrated with other assessments?
- What is the most appropriate assessment type for a given species? E.g., close kin genetic techniques for SBT and school shark?

9.2.5. Improving data collection protocols

- Do changes in data collection protocols makes interannual time-series meaningless (e.g. bird counts)?

9.2.6. Improving Indices of abundance in complex management regimes

- Can we make more use of FIS data in assessments?
- Does the current FIS provide cost-effective abundance information for enough species?
- Are there alternative or modified survey approaches that could be applied to improve utility of these surveys?

9.2.7. Improved future-proofing of our data collection and assessment methods?

- Opportunities should be sought to address the lack of climate change data in assessments.
- Are we missing some fundamental data in our assessments? Such as remote sensing oceanographic data? Are there overseas examples that could be followed?
- What other information is collected that could be useful to evaluate environmental effects? e.g. IMOS data

9.2.8. The value of market-testing data collection and assessment providers?

- The cost/benefits of opening up the providers of risk assessments to competition should be evaluated.
- There is a need for a long term, consistent standard for provision of stock assessment services.

9.2.9. Increase industry data collection

- Can industry provide better bycatch data? Total discards? Spatial stratification? Species identification?
- Can industry provide more length frequency data?

- Protocols are required to guide appropriate resolution for data collection – quantity vs. quality. Can industry-collected data meet a minimum standard and be used in assessments? Need to consider training, feasibility for industry to collect.
- Are EM data for GHATS auto-longline adequately representative of catches / bycatches?

9.2.10. Data collection and storage efficiency

- Options should be considered for optimising data life cycle, collection, storage, archiving, quality assurance and feedback.
- How, where are these data to be stored? – Efficiencies likely to be gained in examining this

The above questions and the results of the reference group workshop were used, together with the analyses and overviews prepared by this project, to formulate a suite of recommendations for improvement in the cost-effectiveness of monitoring and assessment activities in the SESSF.

10. Conclusions and Recommendations

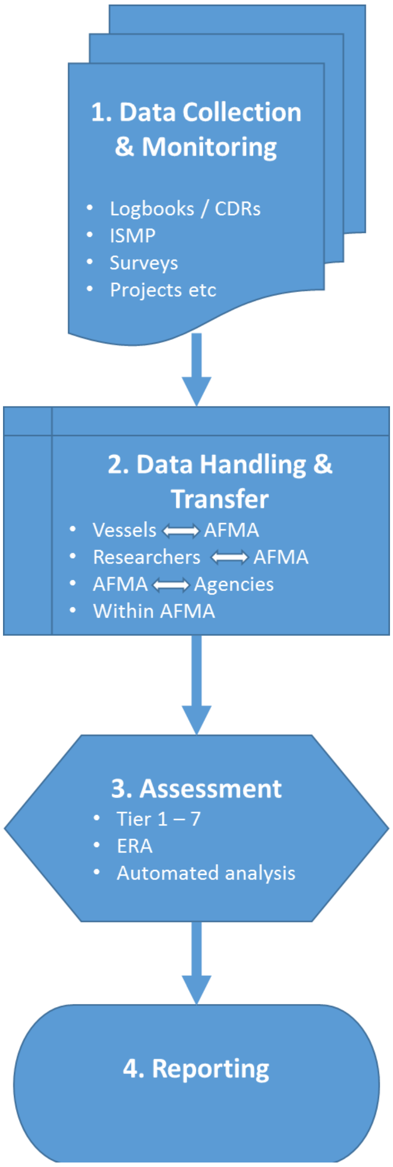
To frame the recommendations from this project, we divided monitoring and assessment processes into four components that roughly reflect the information flow from collection to reporting:

1. Data Collection and Monitoring.
2. Data handling and transfer.
3. Assessment.
4. Reporting.

Recommendations arising from this review, including key stakeholder input, are summarised below. Relative priority, implementation time, feasibility and cost are provided for each recommendation. The high priority recommendations are boxed and highlighted.

10.1. Data Collection & Monitoring

Overall, the project is not proposing to stop or significantly change the types of data that are being collected or how they are used, as international reviews have shown it generally reflects best practice and meets all of the current management needs. Rather, we propose that collection, analysis and reporting of the information is conducted in a more efficient and cost effective manner without compromising the value of the information for management. The key is making sure all of the different systems are integrated, and that the sources of data (ISMP, FIS, CDR, logbooks etc.) have standard formats, are easily cross-referenced, and can be efficiently integrated, shared, analysed, used for assessment and reported on. An efficient monitoring, assessment and reporting system is critical to cost-effective management.



There are a range of recommendations that have come out of this project that have differing priorities and implementation timelines depending on importance and available financial and human resources.

10.1.1. Integrated data

Most of these data collection processes are operating to some extent or another in each sector of the SESSF, but the collection method, frequency, spatial and temporal resolution etc. has often been determined historically or in an *ad-hoc* manner without an integrated approach across data collection areas. Integrated data collection plans are required for each fishery sector to ensure clarity in data requirements and the adoption of the most cost-efficient collection mechanisms. The process for developing a data collection plan for each sector should begin with the reporting and management requirements and be worked back to determine the type, amount and frequency of data required to support this and how it can be collected most cost-efficiently. All proposed data collection should be included in integrated data collection plans.

Recommendation 1. Develop integrated data collection plans for each SESSF sector

Priority:	**High**
Timeframe:	**Short**
Feasibility:	**High**
Cost:	**Low**
Responsibility:	**AFMA with input from RAGs**

Integrated data collection plans are required for each fishery sector. Based on risk and cost trade-offs, these should determine which data are to be collected, using what methods and how much is needed. Data collection plans should include specification and justification of frequency and quantities of data (such as biological measurements, otoliths or observer coverage), and the geographical coverage and spatial stratification required, accounting for information required for fisheries management and reporting and for each stock's agreed assessment. The objective in each case will be to obtain representative data for each stock being assessed.

10.1.2. Areas for data improvement

There are two areas that require significant improvement in the quality and frequency of data collected: recreational fishing catches; and fishery economics. Lack of time-series information on the recreational catch of many shared coastal SESSF species and some deeper-water species compromises assessments and allocation for these species. This is out of the control of AFMA but all efforts should be made to encourage better recording of recreational catch and effort data, particularly for shared SESSF species.

Limited progress has been made over the past decade with development of bio-economic models and application of quantitative MEY approaches to multi-species fisheries such as the SESSF. Some information on fishery economics is collected by ABARES surveys every three to five years. Information on first sale (beach) price is collected as part of periodic economic analysis of GVP and NER. However, comparable series of cost information, particularly at the species level, are not regularly collected. More regular and accurate, industry-supported provision of economic data, including fixed and variable costs of running fishing vessels, and quota trading and lease prices, is required to support management of primary species under an MEY goal as stipulated in the Commonwealth Harvest Strategy Policy. Data requirements for simple and effective economic assessments need to be determined and used to plan data collection.

Socio-economic data or information are currently not collected or used and the socio-economic impact of management decisions is not formally assessed. This precludes the ability to assess the overall economic return to the Australian Community. Options for collecting the socio-economic data required for doing such an evaluation should be considered in the longer term. It is not clear how such data would be used at present, but this may become useful if broader social or societal objectives are included in fisheries management plans under a future ecosystem approach to fisheries management. Social information could best be collected by periodic surveys.

Recommendation 2. Seek opportunities for the cost-effective and regular collection of key economic information for the SESSF.

Priority: **Medium**
Term: **Medium**
Feasibility: **High**
Cost: **Low**
Responsibility: **Industry associations with input from AFMA and RAGs**

Under an MEY framework, opportunities should to be explored by industry in collaboration with AFMA and the RAGs to establish regular collection of key economic information for the SESSF fisheries, as required to conduct MEY analyses.

Another shortfall in the data used for fisheries management commonly noted by stakeholders was related to the understanding of the impacts of environmental drivers, including climate change, on the fishery. Recent modelling of oceanic conditions and water temperature in south eastern Australia shows it to be a global hotspot for climate change (Hobday and Pecl 2014). Fishermen know that temperature and oceanographic conditions affect where fish congregate and can be caught. The Marine Climate Change in Australia Report Card (Booth, 2012) highlighted key knowledge gaps and adaptation responses and found:

- Australian ocean temperatures have warmed, with south-west and south-eastern waters warming fastest;
- The flow of the East Australian Current has strengthened, and is likely to strengthen by a further 20% by 2100;
- Marine biodiversity is changing in south-east Australia in response to warming temperatures and a stronger East Australian Current;
- There may be replacement of small cool-temperate species in southern waters by sub-tropical and tropical species driven by warmer temperatures; and,
- Southward range expansions in south-eastern waters are linked to warming temperatures and a strengthening of the East Australian Current.

They noted with concern that some fishery status reports are still not considering climate change as an issue of significance. In its submission to the Senate Inquiry into the impacts of climate change on marine fisheries and biodiversity, AFMA emphasised it was taking the issue of climate change impacts on the marine environment and Commonwealth fisheries seriously, and was seeking to ensure that management systems can adapt to the changes predicted by the best available science. AFMA recognised the potential impediments to adaptation to climate change by fisheries and management including: behavioural inflexibility (e.g. public, fishers), inflexibility of governance/regulation, the seafood market and fishing business drivers, technological change and limited forecasting capability. The potential influence of climate change on oceanography is high and becoming a more important aspect that needs to be considered in SESSF management and therefore monitoring and assessment. The relative importance and implications of this needs to be determined. There is a need to explore options to improve the collection of basic oceanographic data associated with fishing operations through industry logbooks, data-loggers, the ISMP and/or the FIS.

Recommendation 3. Determine what, if any, environmental data need to be collected by the fishery to support assessment of the impact of environmental drivers, including climate change, on SESSF stocks.

Priority: **Medium**
Term: **Medium**
Feasibility: **Low**
Cost: **Potentially High**
Responsibility: **AFMA, RAGs and research providers**

Previous projects have looked at the influence of environmental factors on SESSF fish stocks but found it was difficult to match or represent the broad spatial and/or temporal scale (hundreds of kilometres) of the environmental/biological parameters with the fine spatial/temporal scales (hundreds of metres) that fishers considered to influence their catches. They suggested that the collection of basic environmental/oceanographic data (e.g. temperature at depth, ocean and weather conditions) by industry members may offer a way of overcoming the problems associated with differences in scale between the environment and fisheries datasets.

Recommendation 4. Investigate options for cost effective collection of fishing-related climate / oceanographic data, adequate to support evaluation of environmental drivers on SESSF stocks.

Priority: **Medium**
Term: **Medium**
Feasibility: **High**
Cost: **Low**
Responsibility: **Fields and definition required from AFMA and RAGs, industry associations**

10.1.3. Electronic reporting and monitoring

It has been highlighted that E-reporting (e.g. logbooks, CDRs) and E-monitoring (e.g. VMS, EMS) generally improves the quality and timeliness of fisheries information (Dunn and Knuckey, 2013). On-board E-reporting systems have software designed to directly capture date, time and location data from GPS, and to retain the data in repeated fields at either the trip level (e.g. vessel and crew details) or set level (e.g. gear configuration). At the point of entry, E-reporting software can ensure that mandatory fields are not skipped, data formatting is correct, range-checking of numeric data is conducted, with use of dropdown boxes and lists to ensure data consistency in non-numeric variables. Further, E-reporting eliminates difficulties in reading handwriting that may lead to mistakes in data entry.

Where appropriate, the first point of data entry should be electronic. In the SESSF, all FIS data are entered electronically. Some ISMP data are also entered electronically but then printed and re-entered into AFMA's observer database. AFMA has an electronic system (GoFish) used by fishers to submit and monitor applications, renew permits, view records of fishing concessions and view quota and catch information. GAB vessels have been using e-Logbooks for over five years, as have some CTS and GHaTS vessels. During the course of this project, there has been a rapid expansion in the use of e-Logbooks by CTS vessels and now more than 50% of CTS vessels are using e-Logbooks to enter and transmit catch and effort data to AFMA. There are significant costs in maintaining duplicate systems for paper logbooks and e-Logbooks.

Many of the fisheries analyses involve the use of accurate catch landings from CDRs to weight up catch estimates from logbooks or observer data. Once vessels have e-Logbooks installed, it is not much of an additional requirement to modify the software so that it can also record CDR information into those logbooks and transfer it to AFMA electronically, again improving the efficiency, accuracy and timeliness of basic data collection.

Recommendation 5. Expedite the complete rollout of e-Logbooks and e-CDRs to all vessels in the SESSF fisheries.

Priority: **High**
Term: **Short (already underway)**

Feasibility:	**High**
Cost:	**Low**
Responsibility:	**Industry, AFMA, service providers**

Fishers in all sectors should move towards E-logs, supplemented by other electronic monitoring systems as required. At this point in time, e-Monitoring should be considered as a tool to improve and validate logbook data.

Recommendation 6. Develop and implement agreed, automated data validation and error checks for e-Logbooks and e-CDRs.

Priority:	**Medium**
Term:	**Short**
Feasibility:	**High**
Cost:	**Low**
Responsibility:	**Industry, AFMA, service providers**

Logbooks are considered to be the most important data source for primary, secondary and byproduct species. Accuracy and removal of errors from logbook catch (retained and discarded) and effort data needs to be improved and can be facilitated by use of E-logbooks.

Data collected from the various sources listed at the top of this section should be complementary to one another, not duplicated, collected in standardised formats and able to be easily integrated for use in assessments. Unnecessary data duplication or excessive data collection must be avoided. For example, the combined quantity of length frequency data currently collected by the ISMP (onboard observers, port measurers), FIS and industry may be unnecessary. Nevertheless, all length-frequency data that are collected need to be captured into AFMA databases in compatible formats, so that they can be efficiently extracted, combined and used in analyses. It is recognised, however, that there may be some necessary level of duplication between data collected by the different sources for the purposes of verification. For example: industry data on TEP interactions requires some level of verification from either EMS or observers; aggregated discard information contained in E-logs required the detail of observer discard catch composition.

Recommendation 7. As part of the development of integrated data collection plans, prevent the collection of duplicate data across multiple data collection systems.

Priority:	**Medium**
Term:	**Medium**
Feasibility:	**High**
Cost:	**Low**
Responsibility:	**AFMA and RAGs, industry associations**

All data collected should be complementary, and unnecessary duplication or excessive data collection must be avoided.

10.1.4. Industry collected data

Apart from logbook and CDR data, there are other data that can be collected by industry. There are examples in the GAB sector where industry has taken over collecting length frequency data on key quota species. Not only has this resulted in considerable savings to industry, but the quality (spatial and temporal extent) and quantity of data available has been improved as a result. Stakeholder perceptions of the reliability of such data should be considered as part of this approach, in part by ensuring that standardised protocols are provided and used for collection of such data.

Recommendation 8. Explore further options for and cost/benefits of industry-collected data, including the preparation of protocols to ensure the compatibility and usefulness of industry collected data.

Priority:	**Medium**
Term:	**Medium**
Feasibility:	**Medium**
Cost:	**Medium**
Responsibility:	**AFMA and Industry**

AFMA and Industry should consider the potential cost-benefits and efficiencies of moving to crew-collected data for some monitoring information.

10.1.5. Data on bycatch and TEP species

Some stakeholders were concerned about the quality and coverage of recording of bycatch and TEP interactions in the fishery. Their perception was that industry was not recording such information accurately in their logbooks and that levels of observer coverage were too low to provide reliable estimates of bycatch interactions. Stakeholders considered that far higher levels of observer coverage were required or alternatively, electronic monitoring systems (EMS), including video monitoring, should be implemented. These expectations are partially based on examples from more profitable fisheries, where the relative costs of observer coverage (compared to the value of the catch) are either lower, or significantly subsidised by the government. The various sectors of the SESSF currently have declining or negative net economic returns and all catch monitoring, including observer coverage, is fully cost-recovered from industry. Other more affordable methods of improving the data quality on the non-retained portion of the catch should continue to be explored. Education of industry about this issue has already occurred and, together with cross-validation of logbook and e-monitoring data, has seen an improvement in reporting. Improvement of logbook recording of non-retained catch and TEP interactions has occurred where video monitoring has been installed on vessels. During the course of the project, electronic logbooks were adjusted to cater for the aggregation of discard species into species groups to enable rapid, practical and more reliable reporting of total discards during fishing operations. This logbook information can then be cross-referenced by observers / EMS to obtain provide greater detail on the species composition of the non-retained catch.

Industry has pointed out that relatively high proportion of monitoring costs are carried by small components of the SESSF, particularly by the GHaTS to monitor TEP interactions. To some extent, these cost are related to the specific bycatch risks posed by different gear types. Presently, EMS is being used to monitor sea lion and dolphin interactions in the GHaT gillnet sector. Innovative and cost-effective approaches need to be explored for monitoring the key risk factors and impacts in these smaller sectors, to reduce monitoring costs without reducing the reliability of the resulting data to assess these risks. Mitigation measures can also be developed to reduce risks. SETFIA-supported trials and adoption of effective seabird mitigation measures for trawls is a good example of this.

Recommendation 9. Explore methods to improve cost-effective monitoring and recording of bycatch and TEP interactions.

Priority:	**Medium**
Term:	**Medium**
Feasibility:	**Medium**
Cost:	**Medium**
Responsibility:	**AFMA specification and Industry**

Quality of recording bycatch, discards and TEP interactions, needs to be improved in a cost-effective manner. Some level of observer and/or E-monitoring coverage should remain as a means of validating and ensuring industry performance in this respect. Innovative and cost-effective approaches need to be explored for monitoring the key risks associated with TEP interactions.

10.1.6. Fishery independent surveys

One particular aspect of the current data collection that received specific scrutiny was the conducting of regular multi-species fishery independent trawl surveys — as distinct from the acoustic fishery independent surveys conducted for Orange Roughy and Blue Grenadier. Concerns about the high cost of a FIS, as a component of the overall cost of SESSF monitoring and research, prompted questions regarding whether the CTS FIS is providing reliable indices of abundance for enough species to justify the continuation of these surveys. As part of this project, the design and results of the FIS for the CTS and GAB) were independently reviewed by NIWA New Zealand to evaluate their effectiveness (Chapter 6). These reviews concluded that:

- The CTS and GAB surveys are appropriately designed, although further attention should be paid to ensuring standardisation of key operational parameters (such as tow locations, inter-vessel calibration, net design) to minimise the contribution of inter-survey variability to process error.
- The GAB surveys provide reliable indices for at least two survey target species (Deepwater Flathead and Bight Redfish) and provide indices with average CVs of less than 30% for the nine other main species (six with average within year CVs less than 20%). The Flathead indices are important for the assessment. The CTS survey provides reliable indices for at least two target species (John Dory and Pink Ling) and useful indices for some other associated species (Common Sawshark, King Dory).

The reviews reached the conclusion that the value of these trawl survey time series should increase over time, not only for individual species monitoring, but also for the development of indices for environmental monitoring. The SESSF RAG (Commonwealth of Australia, 2016) noted that there is soon to be a major emphasis on the impact of fishing on bycatch species as a result of revision of the Commonwealth Policy on Fisheries Bycatch, and that the FIS provides valuable data on species and length composition for bycatch species. However, it is essential that data collected from the FIS is consistent with, and in the same format as, data collected under the ISMP, that such data be collected as part of integrated data collection plans for the fishery, and that the data then get included in databases and assessments, where relevant. The SESSF RAG recommended that, while noting affordability concerns, the Commonwealth Trawl Sector and Great Australian Bight Sector Fishery Independent Surveys should be continued, should alternate and should be conducted biennially, starting with: Commonwealth Trawl Sector – 2016, Great Australian Bight – 2017. Many of the operational recommendations from the NIWA review have already been implemented in the CTS FIS. Options should be explored for generating useful environmental co-variable data from FIS surveys.

Recommendation 10. Optimise use of the sampling and environmental data collection platform provided by the FIS.

Priority:	**Medium**
Term:	**Medium**
Feasibility:	**High**
Cost:	**Low**
Responsibility:	**RAGs and service providers**

Every opportunity should be taken to use the FIS sampling platform to collect information similar to that collected under the ISMP, bit for species that may not be a focus of ISMP observers. Additional environmental / oceanographic data (temperature-depth recorders are already used on FIS trawl nets) may help understand how key environmental drivers, particularly ocean temperature, might affect species distribution, catch composition and catch rates. Targeted collection of biological data on byproduct and bycatch species for which some of the ERA key attributes are missing will improve ecological risk assessments.

10.2. Data documentation, handling, and reporting

There are significant annual costs (~$200,000 per year) associated with data transfer and preparation for reporting and stock assessments. There are a number of reasons why these costs are high including: 1) data must be accessed from multiple AFMA databases (logbook, CDR, ISMP, licencing) and external databases (FIS and state data); 2) there is no formal, standardised process for the data transfer; 3) data fields and formats in those databases can (and do) change without notification to the end users; 4) multiple errors are often found in the data extracted from the databases; and 5) because of a combination of the above, multiple extracts and ongoing communication between AFMA and research providers are usually made each year. These relatively basic technical data issues are not usually detected and addressed until the data are being examined by stock assessment scientists. These issues have been raised repeatedly by the stock assessment scientist over the years.

In addition to the above, although paid for by AFMA and cost-recovered from industry, most of the data from fishery independent surveys (acoustic / trawl / egg surveys), EMS and ageing data is held in different databases by various research providers (including individual private companies) without any formal stipulation of database structure, data format and transfer protocols, or offsite data backup procedures. There is a risk in having important SESSF data (and samples) stored solely with private research providers. This is inefficient, there is a risk of unintentional data loss, and this increases costs to data handling and transfer procedures.

Descriptive, structural and administrative metadata (structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use or manage an information resource) should be available for all data, regardless of source or location. It is understood that AFMA is in the process of addressing many of the above issues through an internal IT project, but until this is completed, data handling and transfer may remain an inefficient and costly component of the SESSF monitoring and assessment process.

Currently, the only digital systems for the automated transfer of data (termed data loaders) from first point of entry to AFMA databases is for E-logbooks and GoFish. The other information sources often depend on paper-based systems where information is posted/transported to AFMA where it is manually key-punched into AFMA databases by either internal employees or (more often) an external contractor ad-hoc digital transfer processes. Systems for the electronic transfer, verification and uploading of data from the first point of capture to AFMA databases need to be developed for all other major data sources (CDR, ISMP onboard, ISMP port and FIS).

Recommendation 11. Develop metadata, including coding descriptions, for all fishery databases, and track changes in coding standards over time.

Priority:	**High**
Term:	**Short**
Feasibility:	**High**
Cost:	**Low**
Responsibility:	**AFMA and CSIRO**

There should be standard metadata for all databases, regardless of the data source and who is collecting it. These should include descriptions of the database structure, fields and coding standards, and how these have changed over time. Any data filtering and error correction ('data grooming') should be well documented and copies of the corrected data kept.

Recommendation 12. Streamline and automate AFMA's data collection, storage, distribution and reporting procedures for all major data sources.

Priority:	**High**
Term:	**Medium**
Feasibility:	**Medium**
Cost:	**High**
Responsibility:	**AFMA**

All fishery data should be captured into relevant AFMA databases in compatible formats that facilitate the extraction and integrated use of all data. Supporting data collection protocols are required to ensure compatibility and comparable reliability of data from all sources. Systems for the electronic transfer, verification and uploading of data from the first point of capture to AFMA databases need to be developed for all other major data sources Efforts are required to optimise the efficiency of data validation, extraction and transfer between AFMA and researchers, to minimise assessment time and costs relating to data preparation; or data preparation should be automated as much as possible.

10.3. Assessments

10.3.1. Tiered assessments and ERAs

Tiered assessment approaches have been developed and applied to stocks in the SESSF for many years based on their importance and whether they were data rich or data poor. A recent review (Dichmont *et al.*, 2016) categorised seven assessment Tier levels outlined in Table 16 based on information availability and outputs from the assessments. The use of a tiered system of assessment methods and associated control rules allows for the development of detailed, single-species integrated stock assessments (e.g. Tier 1) for high information stocks down to the lowest Tiers where data is limited to catch rates or even just catches (e.g. Tier 4 – Tier 7).

Although the harvest control rules can vary widely for a given Tier, they are generally designed to avoid biomass limits (e.g. B_{20}) and, if they are key target species, meet the requirements of HSP to achieve maximum economic yield (a target of B_{MEY}) for the fishery. Potentially included in these tiers are the higher levels of Ecological Risk Assessment for Effects of Fishing (ERAEF), which aims to determine whether there are particular species that are exceptionally vulnerable to the effects of fishing.

Current assessments used in the SESSF are still considered to represent best practice approaches to fisheries assessment, generally meet the requirement of the HSP and can be accommodated in the above tier structure. Tier 1 - 4 quantitative assessments have been applied to the 34 SESSF quota species (or species groups) which are key target species. ERA methods have been applied to the >600 other byproduct, bycatch and TEP species which were managed under the Commonwealth Policy on Fisheries Bycatch, including SAFE assessments for any species found under PSA analysis to be at high risk. Current revisions to the HSP and the Bycatch Policy were meant to have been completed prior to commencement of this project but have been delayed. Initial policy drafts indicate that all retained commercial species will fall under the HSP as commercial species with associated management targets, and byproduct species managed to remain above limits. Non-commercial bycatch and TEP species will fall under the Bycatch Policy and be managed to remain above limits.

In order to assess potential future costs of fisheries assessments and their underlying data needs, we developed a method of classifying species under the categories based on the individual value of species catches compared to the entire value of the fishery and applying default assessment types to the individual species (see section on Species Classification).

With a much larger number of species now falling under the HSP — many with very limited data available — all seven potential tiered assessment methods will likely be required. Although we have only mentioned down to Tier 5 in our assessments (and assumed that costs for Tier four and below will be the same), we propose that the full range of Tiered assessments and ERA methods be considered for species under the HSP based on considerations of available data and cost-effectiveness of assessment methods. The revised ERA methods should remain the main tool to assess byproduct, bycatch and TEP species, against whether there is risk of breaching a limit reference point analogous to the limit reference point under the Harvest Strategy Policy. (See potential PBR assessment of TEPs). If ERAs are to be used for species under the HSP, information or assurance is required that ERAs do measure risk analogous to that of breaching a limit reference point.

There has been some progress towards semi-automated assessments of Tier 4 assessments and triggers. With increasing streamlining of electronic data collection and storage as mentioned in 10.1 and 10.2, there is also increasing potential for fully automated data triggers, assessment and reporting, particularly at the lower Tier levels (Tier 4 – 7). This could result in further cost savings as considered in Option AO.3. A recommendation regarding this is made under the data analysis and reporting section (Recommendation 12).

10.3.2. Ecosystem assessments

Guided by the requirements of the Commonwealth Harvest Strategy Policy and 2005 Ministerial Direction to AFMA, emphasis in monitoring and assessment over the past decade has been on species that contribute significantly to economic returns of the fishery. ERAs conducted for the SESSF fishery components have evaluated the risk posed by the fishery to other bycatch and protected species, and measures have been put in place to mitigate high risks to these species. Under the requirements of the EPBC Act, where there has been evidence of high risk of depletion of an incidentally caught species, individual tailored monitoring, assessment and management activities have been put in place for those species. As mentioned previously, there are concerns that current levels of independent observer monitoring under the ISMP are inadequate, or insufficiently spatially and temporally distributed, to provide reliable estimates of bycatch, discards and TEP species cumulative mortalities, particularly for multi-jurisdiction fisheries. Based on increased requirements that may result from revision of the Bycatch Policy, there may be a need to re-evaluate the methods to provide reliable information on bycatch and TEP interactions.

Management for TEP species must allow the species to recover (if depleted) and to remain as a viable population. Sainsbury (2008) stated that a highly precautionary best practice limit reference point for TEPs is a mortality calculated using the Potential Biological Removals (PBR) method (Wade, 1998) with 'recovery factor' (Fr) of 0.5. This method can be applied with limited information (life history and an estimate of population size) to provide precautionary estimates of maximum sustainable mortality, allowing management to focus on ensuring that fisheries-related mortality remains below such levels. As yet, this method has not been used in Australia, but recent requirements under the Fish and Fish Product Import Provisions of the US *Marine Mammal Protection Act* for seafood imports into America require that fisher impacts on marine mammals fall within estimated PBR limits.

Recommendation 13. Determine reliable PBRs for key TEP species with which interactions occur in the SESSF, and take these into consideration when designing and implementing TEP management plans.

Priority:	**Medium**
Term:	**Long**
Feasibility:	**High**
Cost:	**Low**
Responsibility:	**AFMA, DAWR, CSIRO**

Consider the data and assessment requirements to estimate PBRs for TEP species and whether this is a feasible and cost-effective approach for the SESSF in the medium to long-term.

Based on the above, it would be worth re-evaluating the monitoring techniques and requirements necessary to estimate TEP species interaction levels (and acceptable CVs) across the fishery. AFMA should continue to work cooperatively with the Dept. of the Environment and Energy to collate information on interactions across all fisheries so that cumulative TEP interaction data from all jurisdictions can be integrated. EMS is already being used to monitor marine mammal interactions in the shark gillnet fishery. The CTS is also implementing electronic logbooks with the facility for skippers to estimate aggregated discards, which, when cross-referenced with detailed catch composition from observers, should provide far better spatial and temporal estimates of bycatch levels than is currently achieved.

Recommendation 14. Re-evaluate the temporal and spatial monitoring requirements to provide adequately reliable estimates of bycatch and TEP interaction levels (and associated CVs around these estimates), noting that these can be rare events.

Priority:	**Medium**
Term:	**Medium**
Feasibility:	**Low**
Cost:	**High**
Responsibility:	**AFMA and CSIRO**

There is less evaluation and reporting of the impacts of fisheries on other components of the ecosystem, such as benthic ecosystems. Pitcher *et al.* (2016) estimated trawl footprints from logbook and VMS data and analysed this against the distribution of demersal assemblages to estimate disturbance and potential impact on vulnerable habitats. Generally, the majority of demersal assemblages within Commonwealth trawl fishery jurisdictions were not subject to substantial risk, due to their low exposure to the fishery, but there were some assemblages that had higher exposures to trawling with potential for risk to vulnerable habitats in these areas. They recommended that future resources should be focussed on the small number of more highly sensitive assemblages, particularly those with lower levels of protection, to assess whether vulnerable habitats are present and whether they are at risk from demersal trawl or dredge fishing.

Recommendation 15. As a measure of impact on habitats, utilise fishing position information from logbooks and VMS data to determine the fishery footprint and evaluate trends in fishery spatial impact on vulnerable benthic habitats over time.

Priority:	**Low**
Term:	**Long**
Feasibility:	**High**
Cost:	**Low**
Responsibility:	**AFMA**

In the longer term, this fishery footprint information could be incorporated into ERA assessments relating to benthic impacts, and establish appropriate reference points.

Effects of the environment on fish stock productivity or availability are poorly understood. Appropriate data are not being regularly collected to evaluate environmental effects on fish distribution patterns and catch rates. With increasing evidence of effects of climate change and resulting shifts in distribution of warm and cool water masses, with resulting changes in fish distribution, it is becoming increasingly important to understand how these might be contributing to reduced productivity and catch rates for some stocks, which might in turn be contributing to current high rates of TAC under-catch.

Recommendation 16. Time-series or periodic snapshots of relevant data, such as growth changes, are required to evaluate environmentally-driven productivity changes. Periodic environmental integration / synthesis projects will be required to analyse and interpret environmental effects on fisheries.

Priority:	**Medium**
Term:	**Long**
Feasibility:	**Medium**
Cost:	**High**
Responsibility:	**AFMA / CSIRO**

10.3.3. Frequency of assessments

In addition to recommending the introduction of lower-Tier assessments for some SESSF species, it is recommended that the frequency of all assessments be re-evaluated based on levels of risk, and management and reporting requirements. Due largely to budget restrictions, over the past few years there has been an *ad hoc* reduction in the frequency of various assessments and implementation of multi-year TACs (MYTACs) without any formal testing of associated risks.

Using the proposed species classification, the following assessment scenarios (O.3 or AO.3, compared to current situation C.2) should be used as the basis for determining which surveys are conducted, which species are assessed using which method, and what supporting data preparation and analysis activities are conducted.

Assessment Scenario		Data Frequency	Analysis Frequency	FIS Frequency	ORH Survey Frequency	Assessment Frequency	ERA Frequency	Annual Cost	% GVP	Cost Saving
→C.2	**Current**	**1**	**1**	**2**	**3**	**3**	**5**	**$2,296,649**	**3.4%**	**$1,087,216**
O.3	Option 1	1	3 *	2	3	3	5	$1,896,421	2.8%	$1,487,444
AO.3	Option 1+	1	3 *	2	3	3	5	$1,757,184	2.6%	$1,626,681

Recommendation 17. Scenario AO.3 be considered by RAGs, MACs and AFMA as the long-term goal for SESSF monitoring and assessment scheduling with Scenario O.3 adopted in the short term.

Priority: **High**
Term: **Medium**
Feasibility: **High**
Cost: **Low**
Responsibility: **RAGs, MACs and AFMA**

In the long term, Scenario AO.3 was seen as the most appropriate schedule for monitoring and assessment in the SESSF and is the Scenario recommended for consideration by the SESSFRAG and SEMAC. In this scenario, there is no compromise on current data collection, but major data analyses and assessments are only conducted every three years to support a regime of 3-year MYTACs for quota species. In the intervening years, a system of automated data analysis and reporting will be conducted within AFMA to ensure that no breakout rules have been triggered (single-species assessments or ERAs), TEP interactions are monitored and reported, and there has been no major change in the fishery dynamics (spatial and temporal catch and effort). This Scenario is expected to meet all of the current legislative and policy reporting requirements. However, MSE testing should be conducted to ensure that objectives are met by harvest strategies developed under 3-year MYTACs.

Scenario AO.3 cannot be implemented immediately because it requires appropriate data collection, analysis and reporting procedures to be set up and automated within AFMA. However, the longer-term goal should be to implement automated in-house data-preparation processes to the extent possible, as envisaged under scenario AO.3.

Recommendation 18. Conduct MSE on proposed O.3 and AO.3 scenarios for primary and key secondary species.

Priority: **High**
Term: **Short**
Feasibility: **Medium**
Cost: **High**
Responsibility: **AFMA and research provider**

Management strategy evaluation needs to be conducted to evaluate the risk associated with the proposed frequencies for stocks assessments and for certain data preparation components, to ensure that objectives are still achieved with acceptable risk using 3-year MYTACs under the proposed O.3 and AO.3 scheduling plans.

It is proposed that the assessment methods applied be changed for some species, based on consideration of catch and contribution to GVP, data availability and feasibility of particular assessment methods for certain species. In particular, catches of many or most Byproduct species are too low to justify a Tier 5 assessment, and those determined to be at low risk using ERA would not be assessed further. Lack of a reliable CPUE for some Secondary species would result in these being assessed using Tier 5 rather than Tier 4. Modifying the default assessment type will need to agreed by the relevant AFMA RAG for a few species based on considerations those listed above. It is also expected that species classification and assessment Tier allocation will change over time for some species, as catches and contribution to revenue change.

Unless MSE testing is used to determine harvest control rules for lower Tiers that will achieve the same low risk as Tier 1 assessments, agreed buffers or discount factors may need to be determined for each assessment Tier to ensure comparability of risk (in relation to breaching the limit) between different assessment tiers. These need to relate to the relative certainty of estimates of B and F at different tiers, whether over-fishing is currently occurring, and whether the TAC is being under-caught. Buffers or discount factors should not be needed if MSE testing shows that harvest control rules will achieve the required low risk of breaching limits.

10.3.4. Modification of assessment frequency based on risk mitigation

Following the structural adjustment in 2005–06, fishing effort (boat-days or number of sets) has decreased in the SESSF by about 40% for the CTS and 30% for the GHATS, over the reference effort levels (2004–07) used in the most recent Productivity-Susceptibility Analysis (PSA) ERA for these fisheries (Penney, 2016). Not only has effort dropped, but catches of quota species for many species are significantly below the optimal catches estimated under an MEY framework. 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).

The fact that overall TACs for SESSF stocks have been under-caught by about 52% in recent years has been an issue of concern for some time. The reasons for this under-catch are not understood, and are the focus of a new research project. There may be a number of contributory factors including: reduction in fleet fishing capacity; effort reduction; legislative barriers; spatial closures; changed behaviour of operators; market factors; quota ownership and trading; cost of production; changes in catch per unit of effort; climate change and its impact on oceanographic conditions and potential range shifts of species. It is likely that it is a combination of a number of the above factors. Regardless of the cause, the result is that gross revenue is substantially lower (about 55% assuming prices remained unchanged with increased catches) than could be achieved if full TAC allocations were caught, but also that impact on these stocks is far lower than estimated in assessments that assume the full TAC will be caught. This contributes substantially to the low NER for the fishery, and the concerns over affordability of the high levels of monitoring and assessment originally envisaged for the SESSF. An FRDC project (2016-146) is now underway to investigate this issue.

Byproduct species assessed as low risk in ERAs, and Primary and Secondary species with reliable assessments and substantially under-caught TACs, should be recognised as being at low risk of overfishing. For such low risk species, particularly those that do not contribute substantially to catches or GVP (Byproduct and possibly some Secondary species) there should be re-evaluation of the need for assessment, other than relying on the most recent ERA (particularly SAFE assessments) risk classification. A risk-based scheduling approach, using less frequent assessments for low risk (including under-caught) species, or deferring of assessments until some trigger is breached, is recommended for species with reliable assessments and under-caught TACs.

Recommendation 19. Primary and Secondary quota species with >25% undercatch be assessed less frequently than every three years, or default assessments of such species be deferred until a TAC % catch trigger level of 75% is reached or a maximum of five years has passed since the last assessment. ERAs continue to be conducted every five years. (NB Actual % needs to be agreed by RAG/MAC).

Priority:	**High**
Term:	**Medium (following MSE)**
Feasibility:	**High**
Cost:	**Low**
Responsibility:	**RAGs, MACs and AFMA**

10.4. Data analysis and Reporting

10.4.1. Automated data analysis

If, as recommended in the previous sections, more efficient and better-defined systems for digital data capture, storage and transfer are developed, this will pave the way for the implementation of automated and cost-efficient data analysis and reporting procedures. These procedures could be applied to many situations. Some examples are provided below.

Following extensive development and MSE testing that has now occurred, Tier 4 assessments (and the associated CPUE standardisations) are now relatively straight forward and potential candidates for application of automated analysis. However, poor quality data, lack of verification / validation procedures, changing database structure and data formats, together with *ad-hoc* RAG-initiated changes in assessment methods for individual species, currently prevents this from occurring, and it remains a time consuming and expensive process for stock assessment scientists to re-do this for each assessment.

Current MYTAC breakout rules for Tier 1 and Tier 4 assessments are generally simple arithmetic comparisons of catch rate (or some other parameter) against agreed uncertainty bounds derived from the assessment or raw data. Again, with efficient and well specified data entry, transfer and storage processes, such comparisons could be automatically conducted in a more efficient, timely and cost-effective manner.

Other examples could be automated fishery-wide monitoring of changes in fishing effort and/or spatial or temporal patterns of fishing effort or TEP interactions. These could be easily and automatically assessed agreed reference indicators, thereby producing reports should they move out of acceptable bounds. It has already been proposed that such automated triggers be used to evaluate the need for ERA re-assessment (Penney, 2016). Such quarterly or annual information could be reported to relevant stakeholders and agencies in a timely and cost-effective manner.

Recommendation 20. Develop efficient and automated analysis and reporting of fishery and species indicators, including evaluation of triggers for re-assessment of primary and secondary species.

Priority:	**High**
Term:	**Medium**
Feasibility:	**Medium**
Cost:	**High – requires specific IT project**
Responsibility:	**AFMA with input from RAGs**

Rapid and easily calculated fisheries indicators and triggers should be determined for SESSF species and used to indicate whether risk is likely to have increased to a level that warrants conducting an earlier assessment than scheduled for a species, or alternately that risk has been reduced such that the next assessment may be deferred.

AFMA is developing an annual reporting framework for fisheries under the Fishery Management Strategies currently being developed. Should such analysis and reporting of fishery performance against baseline indicators and targets be automated, it could potentially replace a number of the annual SESSFRAG meeting. If such automated data analysis and reporting procedures were developed, they would need to be tested to ensure they performed as expected.

10.5. Outsourcing and market testing

The budget for monitoring and assessment of the SESSF is a significant component of overall management costs for the various sectors (5 – 11 %), particularly under current conditions of undercaught TACs and declining NER. These ongoing high annual costs monitoring and assessment have raised questions regarding whether these research services could be supplied more cost-effectively, and whether competitive research provision, or periodic market testing, could help to ensure cost-effectiveness.

Recommendation 21. Major research components should be competitively provided, or should be periodically market-tested to ensure that research services are efficient and cost-effective.

Priority:	**High**
Term:	**Medium**
Feasibility:	**Medium**
Cost:	**Medium**
Responsibility:	**AFMA**

11. Implications

The findings of this review have implications for monitoring and assessment of fisheries (particularly mixed species, multi-gear, fisheries). The emergence of ecosystem based fisheries management (EBFM) has placed additional burdens on existing monitoring and assessment programs. For a complex fishery like the SESSF, it is difficult enough to provide regular robust assessments of key commercial species. With recent requirements to evaluate fisheries impacts on bycatch; byproduct; threatened, endangered, and protected species; and the environment more generally, there are expanding requirements (and costs) for information.

Typically, costs are passed onto the commercial participants in the fishery raising concerns about the ongoing affordability of monitoring and assessment. The review has identified potential cost savings relating to the frequency of assessments, the use of data intensive approaches (e.g. fishery-independent surveys) and better integration and preparation of data. Inevitably there will be trade-offs: scientific rigour for cost. However, the review has clearly identified these trade-offs and made these transparent to stakeholders. These trade-offs can be explicitly evaluated and choices made to optimise cost-effectiveness without increasing risk.

This process has implications for research and management of fisheries in a cost-recovery environment. The ongoing roll-out of electronic logbooks and monitoring and data collection systems when combined with automated data analysis and reporting provides necessary efficiencies and cost savings. However, such systems are very much in the developmental phase and further work is required to integrate electronic data collection and monitoring systems into formal assessments, including those required for EBFM.

12. Further Development

Further development is necessary to explore the utility of electronic data collection and monitoring programs. Technology is advancing rapidly and the use of electronic monitoring (e.g. high resolution cameras) to assess fisheries interaction with bycatch and TEPs has potential to partially replace costly observer programs. Remote collection of data from electronic systems can also provide spatially stratified environmental data that could be correlated with variation in species distribution and abundance. This will have particular application in considering the effects of environmental variability e.g. climate change, on fish stock availability and productivity. Consideration of the automation of data collection and monitoring, and its application in formal assessments (species-specific or ecological) will require an examination of existing data collection, data storage, and data transfer protocols. Integrated systems should apply, rather than a suite of disaggregated data management systems.

In the call for expressions of interest for this project, it was requested that the project provider develop criteria for assessing alternative approaches to management drawing on the outcomes of the qualitative analysis of monitoring and assessment. It was envisaged that this stage would include qualitative assessment using expert knowledge and be augmented with a quantitative management strategy evaluation (MSE). The original project proposal contained the following phase as part of the methods:

> **"The expectation is that the qualitative review above will give rise to a priority list of monitoring and assessment strategies that will need to be tested for their efficacy at achieving the range of performance measures for sustainability, social and economic expectations. MSE simulation frameworks will be adapted so that they can test the most promising monitoring and assessment strategies identified in the previous phases of the project".**

In considering the original proposal, the response from the FRDC Board was that the full application should be no more than $300,000 (reduced from $1.3 million) and only address objectives 1 and 2 (Phase 1), thereby precluding any formal MSE work on the outcomes derived by expert judgement. The advice further stated that "The quantitative component is likely to be the most expensive component but is entirely dependent on the outputs from the review".

In a number of different discussions and recommendation in the current project, it is noted that a formal MSE is required "to ensure that any increased risks of adopting this approach are within acceptable levels, noting that an MSE has not yet been conducted to evaluate the implications for management and risk of the current scheduling monitoring and assessment under MYTACs". Explicitly, Recommendation 18 is a high priority to conduct MSE on proposed O.3 and AO.3 scenarios for primary and key secondary species.

Following the outcomes of this project, conducting the MSE is a major area for further development

13. Extension and Adoption

This review has been based on extensive stakeholder consultation, including two workshops with a widely representative Reference Group. Key representatives from research, management and industry, have been regularly consulted to align needs to legislative and policy requirements. The high priority recommendations will be further promoted and discussed (particularly those with cost implications) through the existing formal reference groups (RAGs, MACs) to encourage Adoption of the high priority recommendations.

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15. Appendix 1: Intellectual Property

No intellectual property has arisen from this project.

16. Appendix 2: Staff

Name	Organisation	Project Involvement
Ian Knuckey	Fishwell Consulting	Principle Investigator
Andrew Penney	Pisces Australis Pty Ltd	Co-investigator
Malcolm Haddon	CSIRO	Co-investigator – stock assessment
Matt Koopman	Fishwell Consulting	Policy and data review
Dan Corrie	AFMA	Project administration
George Day	AFMA	Co-investigator
Sean Pascoe	CSIRO	Co-investigator - Economic analysis
Nick Rayns	AFMA	Fisheries management advisor
Simon Boag	SETFIA	Industry advisor
Trevor Hutton	CSIRO	Economic analysis

17. Appendix 3: Report of the 1st Reference Group Consultation Workshop

The first Reference Group consultation workshop for FRDC Project 2014-203: SESSF Monitoring and Assessment – Strategic Review, was held in the Aquarium Room, AFMA, Canberra on 5 December 2014 from 09:00 to 16:30.

1. Welcome and introductions

Participants introduced themselves and were welcomed to the workshop by the Chair, Andrew Penney, and by Nick Rayns as project Principal Investigator and AFMA workshop host. The list of participants is shown in Attachment A.

2. Adoption of agenda

The draft agenda for the meeting was circulated to participants prior to the workshop. It was agreed to drop item 8, on performance measures for evaluating alternative monitoring and assessment options, from the agenda, as there would not be enough time or background information to allow for a productive discussion under this item. The agenda was revised accordingly.

3. Purpose of the workshop

Project Objectives and Scope

The Chair briefly summarised the project planned Outputs and expected Benefits, as documented in the final project proposal. Regarding the Scope of the project, and of the workshop, it was clarified that the project would not be considering the management arrangements for the SESSF in any detail, but rather would focus on evaluation of all aspects of monitoring and assessment of stocks and species caught in the SESSF fishery, and recommendation of improvements or alternative approaches that are cost-effective and will meet current and likely future policy requirements. The project would not be providing commentary or proposed additions or amendments to the Harvest Strategy and Bycatch Policy reviews, dealing with technical aspects of revision of ecological risk assessment (ERA) or risk management (ERM) or, given limited time and budget, conducting quantitative management strategy evaluation of alternative options identified by the project. It was likely that the project would recommend that management strategy evaluations be conducted to evaluate the performance of proposed alternative monitoring and assessment approaches, but this would need to be a separate project.

The purpose of this workshop was to:

- Determine priorities, key concerns and perceived shortcomings in current monitoring and assessment arrangements for the SESSF;
- Canvas broad views on options for improvement in monitoring and assessment arrangements for the SESSF.

Workshop results on these two focus points will be used by the project Steering Group to determine the priorities and final scope for the project, to ensure that the project outcomes address the key interests and concerns of key stakeholder groups.

Reference Group Terms of Reference

Dr Rayns noted that draft terms of reference for the project Reference Group were still in preparation, and would be circulated to Reference Group members for their comment and information once complete.

Action: AFMA undertook to develop draft terms of reference for the Reference Group together with the Steering Group, and to circulate these for comment and information.

For the purposes of the workshop, the initial term of reference for the Reference Group was explained as being to:

- Identify key concerns, perceived shortcomings and opportunities for improvement in monitoring and assessment arrangements, within a risk-catch-cost framework.

Sandy Morison asked how this project would interface with the current processes underway to revise the Commonwealth Harvest Strategy and bycatch policies and their respective guidelines, and whether the project was premature, given the likelihood of changes in these two policies. Nick Rayns noted that this project would be reporting in mid-2016 and that the timing was therefore good, with this project being in a position to develop proposals for cost effective alternatives and feed these into the policy revision process during 2015.

4. Characteristics, Monitoring, Assessment and Management of the SESSF

The project co-investigators gave brief presentations on the characteristics, assessment and management of the SESSF, to provide participants with background information for subsequent discussion of options for improvements. A copy of the combined workshop presentation is available from AFMA on request.

4.1 Characteristics of the SESSF

Ian Knuckey provided an overview of the key characteristics of the main components of the SESSF fishery: CTS; GABTS; GHATS (consisting of the SGSHS and ScHS); and ECDTS. The SESSF has the highest GVP of any Commonwealth fishery, being about $90 million in 2012-23, and lands over 100 species, of which 37 stocks are assessed and 34 stocks are under TACs. It was noted that the status of the majority of these stocks is good, with 2014 being the second year in which no stocks were subject to overfishing. A few stocks that were overfished prior to implementation of the SESSF Harvest Strategy (Blue Warehou, School Shark, Eastern Gemfish, Orange Roughy and gulper sharks) are still under rebuilding plans.

Ian provided an overview of the key characteristics of each of the main SESSF components, including areas fished, number of active vessels, fishing effort levels and catches of the key species (see presentation). The fishery is highly diverse and geographically widespread, presenting different monitoring and management challenges in different areas. Current monitoring and assessment measures include catch and effort logbooks, a fishery independent observer program, fisheries independent trawl and acoustic surveys, additional specialised research and an annual round of stock assessments for a selected array of species, which can differ each year. Together with data management, Resource Assessment Group (RAG), and Management Advisory Committee (MAC) costs, these total about $2.3 million per year, which is largely recovered from industry. While current monitoring and assessment approaches are considered adequate to inform the current management approaches, the question was whether these could be conducted more efficiently and at lower cost. Questions also arose about any additional monitoring requirements that may arise from expected policy revisions, particularly relating to bycatches.

Following the presentation, participants raised the following:

- Simon Boag noted that the SESSF has operated for a century, and that catch, effort, area fished and proportion of the available TAC caught in the SESSF were the lowest on record in 2013-14. The vessels being used were not being replaced and so were now the oldest used. The fishery was still profitable overall, but some components were operating at negative net economic returns. The key priority for industry was to make monitoring and assessment arrangements more cost-effective, while still meeting policy requirements.

- Sandy Morison noted that the total monitoring, research and assessment costs were 2.6% of overall fishery GVP and asked how this compared to other fisheries. It was suggested that the project obtain some comparative information from other fisheries. Jeff Moore observed that total GVP is not necessarily the correct measure with which to compare research costs, and that net economic returns were variable across sectors and time. Keith Sainsbury suggested that the project first focus on what information is required to inform management, and then consider how this can be done cost effectively. Nick Rayns noted that there are no specified benchmarks under the risk-catch-cost framework and that research funding requirements were chosen to achieve an acceptable level of risk at particular catch levels, informed by advice from the RAG and MAC processes.
- Ian Knuckey noted that there could be substantial benefits to be derived from better integration of the various data collection activities, and of resulting data sets, to optimise data collection using existing resources, while avoiding duplication or over-collection. Observer programs provided the most comprehensive data, but currently have low coverage and are being expected to cover an increasing variety of data, such as bycatch interactions. This could detract from collection of important discard, length and age data. What other options existed for these various data types?
- Concerns were raised about the sensitivity of fine spatial scale data. Noting that such data may be needed for certain assessments, it was proposed that the required level of detail be defined so as not to collect more detail than required.
- In response to a query from David Stone, it was confirmed that reference group members could provide their views in writing, initially on the questionnaire that had been circulated. Participants would be provided with an opportunity to revise their questionnaire responses following the workshop if they chose to do so. Participants were also welcome to provide other written input to the steering group if they wished to do so.

Action: AFMA undertook to circulate a request for Steering Group participants to reconsider and revise their questionnaire responses if they wished to do so.

4.2 Assessment of SESSF Stocks

Malcolm Haddon provided an overview of current assessment processes applied to stocks caught in the SESSF, and how assessment results are used to provide annual advice on sustainable recommended biological catches (RBCs), used to inform the AFMA process for setting TACs. SESSF stocks are managed under the SESSF Harvest Strategy Framework, which was implemented before, and substantially informed, the Harvest Strategy Policy, which is currently being revised. Harvest strategies specify which data need to be collected for particular assessment approaches, stock assessment methods depending on available data and the harvest control rule to use to develop RBC recommendations from stock assessment results.

Differences in data availability for different stocks resulted in the development of a tiered stock assessment approach, with different assessment methods being used depending on data availability. Tier 1 assessments (integrated statistical catch-at-age models) are used for data rich stocks, for which catch, effort, CPUE, length-frequency, age-frequency and biological data are available. These provide the most certain assessments, allowing higher catches to be taken at low risk levels, but have the highest monitoring and assessment costs. Tier 1 assessments are therefore usually conducted for the main target species, contributing most of the economic returns to the fishery.

Tier 3 assessments (catch curve and fishing mortality estimates) are used for stocks for which catch, length-frequency, age-frequency and other biological data are available. Tier 4 assessments (standardised CPUE) are used for stocks for which catch, effort and CPUE are available. These assessments have lower data requirements but are usually less certain, requiring catches to be lower to compensate for increased risk resulting from higher uncertainty (see presentation); although preliminary simulations indicate there is not a simple relationship between tier level and relative risk.

In addition to particular data requirements, each assessment requires that certain assumptions regarding species biology, stock dynamics or data properties are met, or else the assessment methods should not be applied.

It was noted that the original choice of assessment approaches to use for each stock was based on data availability at the time of implementation of the SESSF Harvest Strategy Framework, and not on a formal review of which method should ideally be applied depending on biology, stock dynamics and contribution to the fishery. Since then, contributions to catches, stock dynamics (biological productivity), areas fished and data coverage have changed for a number of stocks, resulting in difficulties in applying the chosen assessment methods for some stocks. A review is required of which methods are most appropriate for which stocks. The likely requirement to include additional minor by-product species under a revised Harvest Strategy Policy will also require lower information methods (below Tier 4), or low information ecological risk assessments (ERA), to be applied to these stocks. It was noted that ERAs have already been applied to all species across the fishery.

Following the presentation, participants raised the following:

- The Chair noted that recent problems experienced with attempting to apply the agreed assessment methods for some stocks, as a result of changes in geographic coverage of the fishery or in coverage of observer biological and discard estimation data, and the costs associated with increasing data coverage to compensate for these changes, were a key driver for the project. In particular, it was noted that substantial spatial changes in the fishery (such as those resulting from spatial closures) resulted in increased model uncertainty, and that spatially structured models had high data requirements.
- John Buckeridge requested clarification of the role and specifications for implementation and evaluation of breakout rules. It was explained that these were a recent development necessitated by the recent move away from annual assessments to multi-year TACs (MYTACs) for a number of stocks. Breakout rules should specify conditions under which the stock or fishery appears to have moved outside expected bounds explored in the assessment used to set a MYTAC, such that the MYTAC now posed an unacceptable risk, requiring a revised stock assessment to be conducted. This could occur, for example, if there were indications of substantially reduced recruitment, well below levels assumed in the assessment. However, there has not, as yet, been any formal effort to quantitatively evaluate breakout rule design. The project will need to address specifications for the design of effective breakout rules to be applied for stocks under MYTACs as well as the relative risks involved with using MYTACs on different categories of species and criteria for applying MYTACs to those species.

4.3 Management of the SESSF

George Day provided an overview of management of the SESSF, and how information arising from monitoring and assessment is used to inform management. Substantial effort is put into data collection, management and reporting as part of an annual data requirements planning process (see presentation). Resulting data provide the basis for stock assessments for target and by-product species, and ecological risk assessments for bycatch species. These analyses are presented and peer reviewed by RAGs which provide advice to MACs on RBCs. MACs in turn consider management options, including revisions to TACs, and advise the AFMA Commission, who make final decisions on management actions.

Throughout this process, the assumed risk-catch-cost trade-off is taken into account, to ensure that data collection costs are balanced against requirements to maintain low risk to stocks across the range of information availability and assessment uncertainty at chosen assessment tier levels. One of the key purposes of this review project is to provide guidance for a strategic plan for the next five years for cost-effective collection of the data needed to inform management, and application of a risk-catch-cost trade-off, while continuing to meet evolving policy requirements.

Following the presentation, participants raised the following:

- The Chair noted that some of the drivers for change, and for this project, have resulted from recent changes in management approaches. The increasing move to MYTACs for key species has reduced the number of assessments each year. However, difficulties experienced with some assessments has increased the time and effort required for these particular assessments, and often required more complex spatial analyses with higher data requirements.
- Malcolm Haddon noted that the discount factors currently applied to different assessment tiers in order to apply the risk-catch-cost trade-off have only received preliminary MSE testing. This needs to be done.
- Geoff Tuck noted that CSIRO is currently working on a project (led by Cathy Dichmont) to operationalise the risk-catch-cost trade-off. The results of this work will feed into this review project, providing advice on discount factors and how the risk-catch-cost trade-off can be better implemented.
- Ian Knuckey observed that stocks found to show stability over time under current management approaches are at low risk and should not require annual assessments. Nick Rayns noted that much had been learned about stock productivity and stability over the past ten years, and that some stocks do show stability.

5. Requirements arising from the HSP and Bycatch Policy Reviews

Andrew Penney gave a presentation on the main recommendations arising from the 2013-14 reviews of the Commonwealth Harvest Strategy and Bycatch Policies, particularly relating to tiered assessment and management approaches across the range of species from target through secondary and minor by-product species to discarded bycatch and TEP species. The HSP and Bycatch Policy review reports were released in May 2013. Contributory technical reports to these reviews identified a number of aspects of the current HSP and guidelines that could be improved (see presentation).

The key issue arising from the intention to ensure that all species with which fisheries interact fall either under the HSP or Bycatch policy is the substantially expanded requirement to assess all of these species, particularly many previously unmanaged minor by-product species that will now be included under the HSP. This will require classification of species into categories, after which all stocks will need to be managed according to the category in which they fall. This raises questions about: how to allocate species to categories, what data to collect, how to assess stocks in each category, how to prioritise and schedule assessments, and what do we do about stocks that will not be assessed each year. There will be a requirement for implementation of lower information assessment approaches (Tiers 5 - 7, Dichmont *et al.,* 2013), or for wider application of ERAs to by-product species.

6. Identification of priorities, key concerns and perceived shortcomings

Reference group participants were asked to provide their views on key concerns relating to perceived shortcomings in the current monitoring and management approaches for the SESSF, and to identify their main priorities for improvement relating to these concerns and perceived shortcomings. This was done by going around the table asking each participant in turn to identify and explain their single most important priority or concern, one which had not already been raised, and then repeating this process for each participant's next highest concern until no substantially new issues were raised. Identified priorities were tabulated on-screen as they were raised, ensuring that the wording correctly reflected the issues as raised by the participant, and explained it clearly to others.

After two rounds through all participants, issues raised were either being duplicated, or were subsidiary components of an issue already raised. The resulting table of 35 key concerns identified through this process was printed and provided to all participants who were asked to score their top five priorities from the list in descending order from five to one. The scores provided by each participant were summed into the table of key concerns, which was then ranked in order of descending accumulative score. The resulting list of issues raised, worded as documented during the workshop, are listed in the 2nd column in the tabulated 'Summary of Key Concerns, Priorities and Proposed Solutions' shown in Attachment B, prioritised in descending order of the accumulated scores in column one, as allocated by participants to each concern.

This table provides a prioritised summary of key concerns and perceived shortcomings, as raised and ranked by participants in the workshop. It must be emphasised that this reflects the balance of views in the room at the time, and would differ for a different group of participants. However, by the end of two rounds of issue identification, participants agreed that all of their key concerns were reflected in the table. Given the broad constitution of the Reference Group, it would seem that all of the key concerns were identified. It is also notable that there was a fair degree of consensus regarding which were the most important issues (receiving the highest scores), and which were minor or subsidiary issues (receiving no score).

7. Options for improvement

The main purpose of the project is to develop and evaluate recommendations for alternative approaches or improvements to address perceived shortcomings or requirements for change in current SESSF monitoring and assessment approaches. However, one of the purposes of the workshop was to provide members of the Reference Group with an opportunity to offer their own suggestions on options for improvement in current arrangements. Reference group participants were therefore asked to provide their views on options for addressing the key concerns and perceived shortcomings identified under agenda item 6. This was done in open discussion, addressing the list of concerns one-by-one in the order of priority developed at the workshop and shown in Attachment B. Within the time allocated to the workshop, participants provided suggestions on options to address the top ten issues in the list. The ensuing suggestions are summarised in column three of Attachment B, again using wording agreed and documented at the workshop.

8. Conclusions and next steps

Given that the workshop did not manage to provide suggestions for addressing all of the issues of concern identified at the workshop, it was agreed to provide participants with an opportunity to provide written input on options for addressing the remaining 15 issues after the workshop. The prioritised table of issues and suggested improvement developed at the workshop was circulated by email to all participants after the workshop, giving an opportunity to provide suggestions for addressing those issues not addressed at the workshop. Three written responses were received, plus a few comments by email. Proposed improvements for the 15 concerns not addressed at the workshop were merged into Attachment B. Reference Group members were also offered an opportunity to revise and re-submit their questionnaire responses, should they wish to do so.

Participants noted that many of the concerns raised during the workshop were related, or were components of a broad concern. It was suggested that the concerns raised be grouped or merged into categories relating to, for example, data collection, assessment processes, reference points and ecosystem effects.

> *Action: The Chair undertook to categorise and merge the concerns raised into categories, and attempt to identify key principles relating the concerns under each category.*

The resulting prioritised table of concerns and suggested improvements in Attachment B provides a basis for narrowing and focussing the scope of FRDC Project 2014-203, particularly in relation to addressing key concerns identified by Reference Group participants. This list of key concerns and proposed improvements will be used by the Steering Group, together with concerns already identified and documented by SESSF, Slope and Shelf RAGs, to finalise the project scope and identify perceived shortcomings and opportunities for improvement, as required to meet project Milestone 1. This will provide a final scope to guide the remainder of the project, which will focus on identifying and evaluating options for improvements and alternative approaches to address the identified concerns and shortcomings.

Attachment A: List of 1st Reference Group Workshop Participants and Affiliations

The following members of the Project Steering Group and invited Reference Group members participated in the workshop.

Participant	Affiliation
Mr Andrew Penney	Chair, Pisces Australis, Co-Investigator, Project Steering Group
Dr Nick Rayns	AFMA, Principal Investigator, Project Steering Group
Dr Ian Knuckey	Fishwell Consulting, Co-Investigator, Project Steering Group, SEMAC Research Member
Assoc Prof Malcolm Haddon	CSIRO, Co-Investigator, Project Steering Group, SESSF RAG Research Member
Mr Simon Boag	SEMAC Industry Member, Project Steering Group
Ms Di Tarte	SEMAC Chair
Mr Malcolm Poole	SEMAC Recreational Charter invited participant
Ms Frances Seaborn	SEMAC State Govt Member
Dr Sandy Morison	SEMAC Research Member, Slope RAG Chair, Shelf RAG Chair
Prof John Buckeridge	SESSFRAG Chair
Mr Jeff Moore	EO GABIA, SEMAC GAB Invited Participant
Dr Ilona Stobutzki	ABARES
Dr Keith Sainsbury	AFMA Commissioner
Ms Tooni Mahto	Australian Marine Conservation Society
Mr David Stone	Sustainable Shark Fishery Inc
Mr Mark Nikolai	Tasmanian Association for Recreational Fishing Inc
Ms Kerry Cameron	Department of Environment
Dr Geoff Tuck	CSIRO
Mr George Day	AFMA

Attachment B: 1st Reference Group Workshop - Summary of Key Concerns, Priorities and Proposed Solutions

Score	Key concern / perceived shortcoming	Proposed improvement / solution
31	Inadequate strategic planning of data collection, without clear specification of how data will be used	Apply strategic planning. Start from how the data will be used and work back to requirements. Forecast arising issues – horizon scanning. Provide resources – not just at the end of a RAG meeting. Implement recommendations already made in CSIRO info needs project. Identify gaps and consider options to address these. Align monitoring with objectives for the fishery, as these evolve (e.g. bycatch). Align 5 year data plan with 5-year assessment plan.
24	Data quality and quantity are insufficient to allow robust application of current assessment methods for many quota species, e.g. unreliable indices of abundance, inadequate age data	Investigate options for more or better data, depending on species and decided assessment approach. Verify or improve quality assurance of existing data (e.g. logbooks with EM). Or Apply different methods suited to the available data.
23	Don't understand environmental effects on fish stock productivity or availability, and not collecting the right data to do so	Will need time series or periodic snapshots of relevant data e.g. growth changes. Collect temperature profile info in fishing areas. Will require a periodic integration / synthesis project to review / revise / understand environmental effects. Use FIS to provide some of these data – integrate better with fisheries data.
18	Need greater consistency in design and application of the SESSF HSF, e.g. tiers, discount factors, RCC, alignment of HS and ERA thresholds	Re-do the MSE testing of discount factors, ERA and HS thresholds and other key component of the HSF.
18	Unclear whether FIS providing reliable indices of abundance for enough species to justify their continuation	Evaluate benefits of the FIS. Compare cost-effectiveness of alternative approaches to the FIS.
17	Research and management costs too high and/or annually variable for small or under-caught fisheries	More explicit application of the RCC to reduce costs through application of alternative assessment approaches. Better scheduling of funding of research to balance costs across years. Look at international experiences.
16	Application of MYTACs has not been MSE tested, resulting in reduced confidence in management under less frequent assessments	Alternative MYTAC options and required discount factors need to be MSE tested.
15	Inadequate information or certainty around levels of bycatches and discards	Evaluate CVs around current estimates. Better communication of information. Increased application of EM to provide better estimates. Cross-validate between data sources to verify.

		Evaluate need for better resolution at species level. Evaluate coverage requirements for different reporting options. Re-look at objectives and design of the ISMP.
11	Increasing uncertainty around performance of rebuilding plans	Consider alternative options for monitoring species under rebuilding. Alternative assessment approaches. Alternative data collection options from the start of the plan. Needs to be incorporated into the writing of the rebuilding plan.
11	Data collection planning does not adequately consider integration of data types, prevention of duplication of data collection or collection of unnecessary data or samples; are not collecting some data types	Related to better strategic planning. Data collection should be planned from the outset to reduce overlap, ensure adequate but not unnecessary data are collected.
10	Unclear whether level of independent monitoring is adequate to provide reliable estimates of TEP species cumulative mortalities, particularly for multi-jurisdiction fisheries, and to assess resulting impact on populations	Re-evaluate the temporal and spatial coverage required to monitor TEP interactions, noting that these can be rare events. Consider alternative or supplementary methods (such as video monitoring) to increase coverage. Continue to work cooperatively with Dept of Environment to report interactions across all fisheries so that TEP interaction data from all jurisdictions can be collated.
8	Concerns at inadequate collection of total catch (F) of stocks shared with other sectors or jurisdictions	
8	Have not assessed whether observer data is representative of the fishery	There have been a number of planning exercise to provide guidance on observer coverage and biological sampling levels required for current assessments under the ISMP program. However, there needs to be re-evaluation of coverage levels required to provide reliable information on more recent requirements relating to monitoring of e.g. TEP interactions.
7	Will current monitoring and data collection be adequate to detect early warning of declines to B_{lim} of additional species brought in under the HSP?	Determine data requirements to detect trends in all species brought under HSP, depending on the assessment method applied to each species. Consider alternative options for collecting data, such as electronic monitoring or reliable proxies, if data are insufficient for stock assessments to provide trends.
7	Incorporation of economic information and application of MEY approaches inadequate in multi-species fisheries	
7	Concern that reference points established in the 1980s are not relevant to current stocks, notably B_{lim}; particular concern about now trying to apply this to additional species	

7	Redesign of the monitoring and assessment will have to take account of articulation of acceptable levels of risk for bycatch species.	
6	Low confidence in accuracy, adequacy or representativeness of biological data, e.g. outdated biological data	
6	Inadequate collection of economic data.	Data requirements for simple and effective economic assessments need to be determined and used to plan data collection. Quota leasing may play a significant role in catch viability and under-caught TACs. The financial effect of the 28 day reconciliation period may contribute to discarding. The effect of these factors needs to be evaluated.
5	Difficulty of monitoring and quantifying underwater marine mammal interactions with gillnets	Passive acoustic monitoring should be more widely used to identify spawning aggregations and estimate biomass.
5	Is current monitoring adequate to detect spatial or temporal localised depletion?	
5	Concerns that data are not adequate to capture spatial stock structure, and stock assessments not catering for actual spatial structure	
4	Concern at insufficient knowledge of impact of fisheries on benthic ecosystems	Research planning should include development of a research program to evaluate ecosystem impacts, focussing on the most important aspects most useful to informing ecosystem-based fisheries management.
4	Insufficient evaluation / explanation of the way that the precautionary principle is applied in assessments	This should be addressed by formally evaluating and documenting the application of a risk-catch-cost framework, including tested discount factors to account for higher uncertainty.
3	Inadequate formal procedures or quality control of fisher-provided data	Guidelines should be prepared (in simple form) and provided to industry. Need to document procedures and provide flow charts for a clear HCAP-type procedure identifying steps and responsibilities relating to industry data collection.
3	Research procurement has not been market tested to ensure cost-effectiveness	
2	Inadequate integration and coordination between phases in the process: monitoring > data collection > data preparation > assessment	This needs to be addressed by better and more integrated planning. Perhaps a Flow Chart establishing time frames, various steps and required actions and person/persons responsible for each step.

2	Social data / information currently not collected or used	The socio economic impact of management decisions appears to not be addressed at present, precluding the ability the ability to assess the overall economic return to the Australian Community. Options for doing so should be considered.
1	Confusion around the application and meaning of the terms ‘bycatch’, 'tiers'	This needs to be addressed to ensure that such terms have a specific and defined meaning, and are used as defined across all components of the assessment and management process.
1	Assessments focus on retrospective analysis and trends; need more forecasting of longer term outlooks for fisheries	Need to consider options to address the potential economic loss from biomass pulses generated by environmental variations or recruitment, which may not be available for two years under current RBC setting processes.
	It is unclear what action should be taken when a ‘breakout’ rule or catch trigger is broken	The design and implementation of breakout rules needs to be formally evaluated, and guidelines provided for their use, including responses when they are triggered.
	FIS data are not integrated into the data systems and processes	This should be done. Reasons why it is not done need to be explored and processes developed to facilitate data integration.
	Are under-caught TACs being adequately dealt with in subsequent stock assessments?	
	There are different levels of confidence in different data types from different sources.	
	Initial allocation of species to assessment types was based on available data	Species categorisation needs to be objectively reviewed, particularly for additional species brought under management under a revised HSP.

18. Appendix 4: Report of the 2nd Reference Group Consultation Workshop

The second Reference Group consultation workshop for FRDC Project 2014-203: SESSF Monitoring and Assessment Strategic Review, was held in the Freycinet Room, CSIRO, Hobart on 15 June 2016 from 09:00 to 16:15. The workshop participants are listed in Attachment A.

Workshop documents

All information presented at the workshop was provided in the form of a presentation, supported by a scenarios analysis spreadsheet and six documents:

- NIWA 2015 - Review of CTS Fishery Independent Survey.pdf
- NIWA 2015 - Review of GABTS Fishery Independent Survey.pdf
- Bergh 2016 - Review Research Assessment Monitoring.pdf
- Penney and Knuckey 2016 - SESSF Assessment Scenario Evaluation.pdf
- Pascoe and Hutton 2016 - Vessel level economic analysis.pdf

These documents were circulated to all participants prior to the workshop. The presentation and analysis spreadsheet were provided to participants after the workshop.

1. Welcome and introductions

Workshop Facilitator, Andrew Penney, welcomed all participants, who introduced themselves.

2. Background and purpose of the workshop

Ian Knuckey, Project Principal Investigator, outlined the purposes of the workshop as being:

- To present the results of cost evaluations of alternative monitoring and assessment scenarios.
- To identify risk trade-offs under alternative scenarios.
- To identify viable future options for an effective balance of monitoring and assessment options.

3. Outcomes of the 1st Workshop

Andrew Penney provided a summary of the outcomes of the 1st reference group workshop, held on 5 December 2014..The key concerns and priorities raised by participants in the 1st workshop grouped themselves into four categories: monitoring (31 % of the count of issues raised), assessment (27%), ecosystems (23%) and cost (14%). The project intends to make recommendations to cover the issues raised at that workshop. The 2nd workshop is intended to develop some of these recommendations.

4. Project Methods and Inputs

4.1. Legislative requirements and implications of policy reviews

George Day and Ian Knuckey presented an overview of the requirements arising from the legislative and policy framework, as well as the implications of reviews of the Harvest Strategy and Bycatch policies. The importance of species classification (as either primary, secondary, byproduct or bycatch) was emphasised in the context of determining the applicable policy (Harvest Strategy or Bycatch), management target and assessment method and for each species.

4.2. Data sources and assessment types

Ian Knuckey listed the data sources used in the SESSF, being: logbooks/e-logs; catch disposal records; observer data (and electronic monitoring); Fishery Independent Surveys; ageing data; and industry length frequencies. Explanation was provided of which of these data sources are used in the various assessment tiers, including ERAs.

Q: Is the reliability of data evaluated when incorporating data into assessments?

A: An essential aspect of every assessment method is the statistical evaluation and reporting of the variance or uncertainty in the input data. This is then explicitly factored into how the data are used in the assessment.

4.3. Costs of monitoring and assessment

George Day provided an overview of the total management costs of the SESSF, including AFMA fishery and data management costs, which total ~9% of fishery GVP. He then presented the default component costs used in evaluating alternative monitoring and assessment scenarios for: fishery data collection and analysis components; individual assessments at each tier; and allocation of FIS survey costs between species.

Q: There were numerous questions about what costs had and had not been included in evaluating alternative SESSF scenarios.

A: It was emphasized that only costs that could be attributed in some way to individual species or individual assessment types, and might be changed depending on the scenario, had been included in scenario evaluations. Costs that could not be attributed to species, or that were fixed overall costs, were not included in the scenarios.

A: Costs such as AFMA general management and data management costs, current E-monitoring cost and separate research projects other than the assessment contracts, were not included. These can all be added on after evaluation of alternative scenarios.

A: Attributable costs were only those relating to the cost of doing an individual ERA or assessment now, and did not include the costs associated with the original development of those methodologies.

Participants requested that the terminology used to define categories of FIS species be changed so as not to be confused with the definitions of Primary and Secondary species used for species classification for policy purposes.

4.4. Current situation

Ian Knuckey provided an overview of the current situation in the SESSF in terms of catch trends, GVP trends, net economic returns and current levels of TAC undercatch. The CTS currently has positive but declining NER, while the GHaTS fishery has negative NER. Recent catches have been <50% of TACs for 23 species. This suggests that, in terms of the Risk-Catch-Cost trade-off, the fishery has moved from a being of being overfished and overly-risk in the 1980s - 1990s to currently being under-caught and overly expensive and conservative.

4.5. International review

Andrew Penney provided a few observations on the international review conducted by Dr Mike Bergh. He noted that the reviewed fisheries provided ideas on options for improving monitoring and assessment, but that care must be taken in transferring practices from those large and economically highly productive fisheries to the smaller Australian fisheries. The reviewed fisheries adopt fairly formalised approached to prioritising assessments, focussing attention (and expenditure) on high priority or high risk fisheries, leaving others unassessed.

Q: It was noted that the USA tends to have fixed processes in place (such as surveys) but do not necessarily regularly evaluate risk to all stock components.

Q: Does the MSC accreditation system offer useful guidance on how we should be monitoring and assessing stocks?

A: The MSC standards are, in large part, based on successful approaches implemented by leading fisheries management agencies, including those in Australia. There is iterative feedback between the MSC and management agencies on best practice for monitoring and assessment. AFMA continually monitors MSC and other 3rd party certification standards to ensure that Commonwealth fisheries management practices remain compatible with those standards, although does not endorse any particular certification scheme.

4.6. Review of the Fishery Independent Surveys

George Day provided an overview of the conclusions and recommendations of the reviews conducted by the New Zealand National Institute of Water and Atmospheric Research (NIWA) of the CTS and GABTS Fisheries Independent Surveys. These reviews concluded that the surveys provided FIS provides useful abundance indices for about half of the species across the GABTS and CTS fisheries. The surveys could be a useful input to future stock assessments, but their influence is currently limited the short series of survey estimates. They also provide useful data on species and size composition for bycatch species.

5. Project findings

5.1. Species categorisation, targets and default assessments

Andrew Penney provided an explanation of the spreadsheet developed by the project for the purposes of exploring alternative assessment scenarios. The settings used to develop the proposed initial classification of species (between primary, secondary, byproduct and bycatch) were explained, and the resulting classification of the 670 SESSF species was shown. Default management targets (MEY, MSY and >LIM) and default assessment tiers were proposed for the species categories.

5.2. Alternative monitoring and assessment scenarios - costs and trade-offs

Alternative scenarios

The spreadsheet was used, with the default classification and cost component settings, to explore ten alternative monitoring and assessment scenarios, ranging from a doubling of observer coverage, through a default scenario reflecting original intentions, the current scenario and seven scenarios with decreasing frequency of assessments (1, 3 or 6 years) or ERAs (6 or 12 years), decreased frequency of some data analysis and collection components (1 or 3 years) and application of lower information assessments to some species. Costs of these scenarios (counting only the directly attributable monitoring and assessment costs, excluding management, E-monitoring and other projects) ranged from 5.5% of GVP for the doubled observer coverage scenario, to 3.4% of GVP for the current scenario to 2% of GVP for the scenario with least frequent assessments.

Scheduling of assessments

Using the results of the current scenario analysis (average 3.4% of GVP spent on monitoring and assessment each year), Ian Knuckey provided two examples of how alternative scheduling of assessments could be used to smooth out costs between years, If assessments and surveys are scheduled to coincide, annual costs would fluctuate substantially between 2.2% and 5.3%. However, by spreading assessments between years and scheduling them between surveys, annual costs would fluctuate between 3.0% and 3.7% of GVP. It was noted that spreading of assessments across years did limit the options for reducing the frequency of CPUE and ageing data analysis.

Lost opportunity costs

Using the results of the alternative scenarios analysis, Andrew Penney presented an overview of the lost opportunity costs that might be expected to arise from resorting to lower information assessments for the TAC species, as a result of assumed discount factors and lower TACs from such assessments. Provided the TACs for these species are fully caught, these lost opportunity costs could reach ~$24.7 million under an All Tier 5 scenario. The current sce4nario would have lost opportunity costs of ~$1.6 million.

However, TACs are currently undercaught, with only about 48% of the combined TAC for all TAC species being caught in 2015-16. This undercatch largely negates the potential lost opportunity costs. Using actual average 2012-14 catches, there would still be some lost opportunity costs under an All Tier 5 scenario (~$4.2 million), but the current scenario in fact offers a benefit of ~$541,000 compared to doing all Tier 1 assessments.

Vessel level economic analysis

Trevor Hutton presented a more detailed vessel level economic analysis, incorporating recent data from ABARES on the ranges in other operating costs incurred by vessel operators. Taking into account the opportunity cost of the owner-operator, labour as well as capital, average vessel economic profits in 2012-13 in the CTS were $109,000, with most vessels earning positive economic profits. In contrast, average economic profits in the GHaTS were –$25,900, with most boats experiencing economic losses. If the full TACs were caught, revenues in the CTS could double. GHaTS revenue could increase by ~$31,000 per vessel, although with half the vessels still experiencing economic losses.

> Q: Were price elasticity and transactions costs (relating to quota trading if TACs were much lower than at present) taken into account?
>
> A: Not in this initial analysis. Data on these two factors are less readily available, although assumptions could be made.
>
> Q: Could an MEY bio-economic analysis not be conducted to take account of all of these factors?
>
> A: No bio-economic model has yet been developed for the multispecies SESSF, in which many species would be managed to MSY or >LIM. Given cost data limitations, such a model may not be feasible.

Risk and information trade-offs

Ian Knuckey presented a consideration of the potential trade-offs in risk and information availability that could arise as a result of reducing data collection, data analysis and assessment frequencies. There have already been substantial savings compared to original intentions as a result of introduction of 3-year MYTACs, and conducting FIS surveys only every two years. Further reductions in assessment frequency or analysis of some data components come at a cost of reduction in data or increased uncertainty and risk as a result of less frequent assessments.

6. Striking the right balance

The afternoon session was devoted to development of recommendations to address what were considered by participants to be the main issues relating to monitoring and assessment of:

- Primary and Secondary species
- Byproduct species
- Bycatch species
- Threatened, endangered or protected species

Participants were divided into three breakout groups and each group was requested to provide a few prioritised bullet points on:

- What is the essential and achievable minimum that needs to be done to meet legislative and policy requirements?
- What do we need to keep as is? What needs to change?

The range of affiliation and expertise was spread across the three groups and each group chose a spokesperson to report back on the group recommendations. Participants and spokespersons in each group are shown in Attachment A.

Breakout groups report back

Group 1 (spokesperson: Simon Nichol)

Monitoring:

- For primary and secondary species, operational catch and effort from logbooks remain the most important data; could E-monitoring provide validation of logbooks?
- Observer data are required to provide discard estimates to determine total catch; to what extent could this be provided by E-monitoring?
- Length frequency and ageing data are required for Tier 1 assessments; does E-monitoring have any role to play here?
- Some of the current biological data may be outdated and should be updated to reflect recent changes in biology or productivity.
- For byproduct and bycatch species, we need reliable estimates of discards, including live vs. dead discard ratios, provided by observers and/or E-monitoring.
- For TEP species, we need reliable estimates of interaction ratios; how can these best be collected?

Assessment:

- The assessment tier structure should be about the relative reliability of estimates of F and B produced by assessments at different tiers.
- Buffers (TAC discount factors) should be applied based on the certainty of assessments; there is an interplay between buffers and the frequency of assessments - more frequent assessments should mean smaller buffers.
- There may be a need to use multi-species assessments and ecosystem models to evaluate the effects of climate change.
- Byproduct species should be assessed similarly to bycatch, using ERAs against a limit reference point. There should be re-assessment triggers for high risk or medium risk species. Tier 5 (average catch) approaches may be useful for key byproduct species.
- Bycatch species should primarily be assessed using ERAs each 6 - 10 years against a limit reference point, with evaluation of re-assessment triggers between assessments.
- The risk equivalency of ERAs and assessments against a limit reference point needs to be shown; what is the relative risk equivalency of low, medium and high risk species in relation to the limit reference point?
- For TEP species, risk and impact need to be minimised; how can this be monitored and demonstrated?
- Determination of population status of TEP species needs separate dedicated research projects to determine cumulative impacts and evaluate effectiveness of mitigation.

General:

- Reasons for TAC undercatch should be determined through a separate research project. Problems with current assessments may not be picked up by simply continuing these assessments.

Group 2 (spokesperson: Geoff Tuck)

Monitoring:

- Logbooks are essential and there could be cost savings if these can be improved to give reliable data on all fishery aspects.
- ISMP and/or E-monitoring are required to validate logbooks, or to provide data not reliable from logbooks.
- Length-frequency data are currently generated by ISMP onboard and port, FIS surveys and industry. These need to be rationalised into an efficient sampling programme.
- Could frequency of otolith collection and ageing be reduced, e.g. to every second year?
- Improvements are needed in estimates of discards of byproduct and bycatch species. E-monitoring could be used to support improved logbook reporting; this could entail increased costs.
- TEP interactions are currently incompletely reported, largely as an add-on to existing monitoring; needs to be improved.

Assessment:

- Improved efficiencies are needed in data validation, processing and transfer from AFMA to CSIRO.
- Optimal frequency of assessments and ageing needs to be tested using MSE.
- Average ERA costs for bycatch (and byproduct) species are inexpensive per year, so look for efficiencies elsewhere rather than reducing ERA frequency.
- There is currently minimal quantitative assessment of TEP interactions. How could this be improved?

Group 3 (spokesperson: Nick Rayns)

Monitoring:

- There should be a move towards replacing all paper-based reporting with electronic reporting (E-logs).
- Wherever possible, do away with duplicate collection of data. Can CDRs be replaced by logbook reporting only? Perhaps supplemented with E-monitoring to validate logbooks?
- Standardised data collection methods and programmes should be used, rather than one-off data collection by individual projects. Data collection by individual research projects needs to be aligned with overall fishery monitoring and reporting requirements.
- Data collection needs to be coordinated into an integrated approach, doing away with duplication while ensuring adequate coverage. In doing so, it must be ensured that all data are in a format useable for analysis.
- Length-frequency data collected by industry need to be integrated into length-frequency data collections in a compatible and cost-effective manner.
- Should FIS surveys continue? It should be determined whether the FIS surveys are contributing cost effectively to assessments, and whether trawl survey indices are useful. A timeframe should be set for this decision.
- Accurate estimates are required of TEP interactions, and whether the resulting fisheries impact is detrimental to the species population. The approach for doing so may need to differ for different species; E-monitoring may work for shark line fisheries, but not as effective for trawl fisheries.

Assessment:

- The reliability of some data components for assessment of some species needs to be reviewed e.g. CPUE for blue eye.

- Consideration should be given to not doing stock assessments if a) there is high confidence in initial assessment and TAC, and only catching about half the TAC; or b) scheduling assessments so that assessment work is only done in alternate years to achieve lower overall costs.
- Would there be conditions under which a species could be managed without any further assessments?
- Where assessments are not done annually, mechanisms could be explored to smooth costs over years. Alternately, would having costs varying between years provide the most cost-effective overall option?

General:

- Further analysis is required to show which variables in the alternative scenarios analysis have most impact on monitoring and assessment costs.
- Are there any limiting factors that could be cost-effectively addressed to increase fishery economic performance?
- Well specified periodic reviews (each ten years or so) of key components of fishery monitoring and assessment approaches should he conducted, with costs built into fishery management cost structure.

Overview of Breakout Group recommendations

Expectedly, there were differences in the emphasis and balance of recommendations made by the three breakout groups. Between them, the three groups covered most of the recommendations, or at least posed questions about such recommendations, on all the key issues of concern raised by participants at the 1st reference group workshop.

There were also notable similarities in recommendations by the three groups on a number of aspects of monitoring and assessment, indicating these to be the most important. The summary below attempts to synthesise the most important or common elements in the recommendations by the three groups.

Monitoring:

- Logbooks are considered to be the most important data source for primary and secondary species. Reliability of these needs to be improved, and they should move towards E-logs, supplemented by other electronic monitoring systems. E-monitoring should be considered as a tool for validation of logbooks.
- Duplicate data collection must be avoided Where data are collected in multiple ways, these need to be rationalised or integrated into an efficient system.
- Efforts are required to optimise the efficiency of data validation, extraction and transfer between AFMA and researchers, to minimise assessment time and costs relating to data preparation.
- Length-frequency data collected by ISMP, FIS surveys and industry need to be rationalised and integrated. All length-frequency data need to be captured into AFMA databases in compatible formats, so that they can be efficiently extracted, combined and used in analyses.
- Coverage of byproduct and bycatch discards, and of TEP interactions, needs to be improved. Observers may remain the best way to collect such data. E-monitoring may be an option for monitoring interactions with certain TEP species.
- There remain questions or concerns about the cost-effectiveness of high-cost monitoring activities such as the FIS surveys.

Assessment:

- Management strategy evaluation needs to be used to determine optimal or acceptable frequencies for stocks assessments and for certain data preparation components, such as ageing.
- Infrequent assessments, or deferring of assessments until some trigger is breached, may be efficient for species with reliable assessments and under-caught TACs.
- Buffers or discount factors are required between different assessment tiers, and need to relate to the relative certainty of estimates of B and F at different tiers.
- ERAs should remain the main assessment tool for both byproduct and bycatch species, with both being managed have a low risk of breaching a limit reference point analogous to the limit reference point under the Harvest Strategy Policy.
- Additional information or assurance is required that ERAs do measure risk analogous to that of breaching a limit reference point.
- Assessment of population status, effectiveness of mitigation measures and cumulative impact of fisheries on TEP species requires separate dedicated research projects.

General:

- Better understanding is needed of the reasons for TAC undercatch. A separate research project should address question such as: Are there any concerns relating to using single-species assessments in a multi-species fishery? Are there effects of climate change or other productivity changes that are not captured by current assessments? Are there operational constraints on catching TACs that could be reduced to improve fishery economic performance?

7. Conclusions and next steps

Ian Knuckey explained that a workshop report would be circulated to participants within the next two weeks. Recommendations arising from the workshop would be incorporated into the final report of the project.

Participants were thanked for their constructive participation and useful recommendations and the workshop was closed at 16:15.

Attachment A: 2nd Reference Group Workshop Participants and Affiliations

The following members of the Project Steering Group and invited Reference Group members participated in the workshop. Project Team members are shown in ***bold-italics***. The allocation of participants to the discussion Breakout Groups is shown, and group spokespersons are <u>underlined</u>.

Participant	Affiliation	Breakout Group
<u>Simon Nichol</u>	ABARES	1
Thomas Krijnen	Dept of Agriculture and Water Resources	1
George Day	AFMA	1
Di Tarte	SE MAC Chair	1
David Stone	Industry	1
Beth Fulton	CSIRO	1
<u>Geoff Tuck</u>	CSIRO	2
Tony Harman	Dept of Agriculture and Water Resources	2
James Woodhams	ABARES	2
Jeff Moore	Industry	2
Malcolm Poole	Recreational	2
<u>***Nick Rayns***</u>	AFMA	3
Nathan Hanna	Dept of the Environment	3
Sandy Morison	SE RAG Chair	3
Simon Boag	SETFIA	3
Trevor Hutton	CSIRO	3
Malcolm Haddon	CSIRO	3
Facilitators		
Ian Knuckey	Project PI, Fishwell Consulting	1 - 3
Andrew Penney	Workshop Chair, Pisces Australia Pty Ltd	1 - 3
Apologies		
Kerry Cameron	Dept of the Environment	
Frances Seaborn	SEMAC member, Dept Primary Industries, Parks, Water and Environment, Tasmania	

19. Appendix 5: SESSF legislation and policy documents

19.1.1. Fisheries Management Act 1991 No. 162, 1991 as amended [9]
Description
The Fisheries Management Act 1991 is the principle legislation that defines the objectives, powers and functions of AFMA. The Act addresses management of fisheries plans, statutory fishing rights, granting of permits and licences, offences for the taking of certain marine species, cooperation with States and Territories and surveillance and enforcement amongst others.
Objectives
The Fisheries Management Act 1991 describes the objectives that must be pursued by the Minister in the administration of the Act and by AFMA in the performance of its functions: a) implementing efficient and cost-effective fisheries management on behalf of the Commonwealth; and b) ensuring that the exploitation of fisheries resources and the carrying on of any related activities are conducted in a manner consistent with the principles of ecologically sustainable development (which include the exercise of the precautionary principle), in particular the need to have regard to the impact of fishing activities on non-target species and the long term sustainability of the marine environment; and c) maximising the net economic returns to the Australian community from the management of Australian fisheries; and d) ensuring accountability to the fishing industry and to the Australian community in AFMA's management of fisheries resources; and e) achieving government targets in relation to the recovery of the costs of AFMA. In addition to the objectives mentioned in subsection (1), or in section 78 of the Act, the Minister, AFMA and Joint Authorities are to have regard to the objectives of: a) ensuring, through proper conservation and management measures, that the living resources of the AFZ are not endangered by over-exploitation; and b) achieving the optimum utilisation of the living resources of the AFZ; and c) ensuring that conservation and management measures in the AFZ and the high seas implement Australia's obligations under international agreements that deal with fish stocks; and d) to the extent that Australia has obligations: (i) under international law; or (ii) under the Compliance Agreement or any other international agreement; in relation to fishing activities by Australian-flagged boats on the high seas that are additional to the obligations referred to in paragraph (c)—ensuring that Australia implements those first-mentioned obligations; but must ensure, as far as practicable, that measures adopted in pursuit of those objectives must not be inconsistent with the preservation, conservation and protection of all species of whales.
Measures by which the objectives are to be attained
Given their objectives are nearly identical, the measures by which the objectives of the Act are to be attained could be good be assumed to be the same as for the SESSF Fisheries Management Plan 2003 (see

[9] Anon. (2014). Fisheries Management Act 1991 No. 162, 1991 as amended, Office of Parliamentary Council, Canberra. http://www.comlaw.gov.au/Details/C2004C00260/8ad53108-5267-45fc-9b57-548e46c66a81 (Accessed 10/11/2014)

below).

Broad categories of data collection needs
Assessments of target species Assessment of bycatch and discards Ecosystem Verification/improve data collection Licencing Socio-economics

Specific data collection activities

√	Logbook	√	Dedicated research projects	√	Owner / vessel registry
√	CDR	√	Interaction/bycatch studies	√	Permits
√	State fishery landings	√	Survey of fishing gears	√	Quota allocation
√	Recreational catch estimates	√	Reference points	√	Quota trading
√	Observer / port measure	√	EMS	√	Economics
√	Age data	√	Compliance	√	Logbook Interactions
√	Industry collected length freq.	√	VMS	√	MSE
√	Fishery Independent Surveys	√	ELogs		
√	Biological / stock structure studies	√	Education		

Outputs

- resource assessment groups compile regular fisheries assessment reports containing information on monitoring, accuracy and consistency of fisheries data, implementation of entitlement schemes, reference points, harvest strategies and TAC setting for quota and non-quota species and stock recovery strategies
- regular reports regarding the status and management of the fishery
- an annual report for each financial year that includes a statement of the extent to which the performance criteria were met
- data to enable (i) timely evaluation of the effectiveness of the measures implemented to maintain the resources of the fishery at, or rebuild those resources to, an acceptable level; and (ii) timely modification of those measures

19.1.2. Fisheries Administration Act 1991 [10]

Description

The Fisheries Administration Act 1991 sets out the requirement for establishment of AFMA and the Fishing Industry Policy Council. It describes AFMA's structure, functions, powers and reporting responsibilities.

Objectives

The Fisheries Administration Act 1991 contains the same objectives as the Fisheries Management Act 1991, but also requires AFMA to pursue the objective of ensuring that:

a) The exploitation in the Australian Fishing Zone (as defined in the Fisheries Management Act) and the high seas of fish stocks in relation to which Australia has obligations under international agreements and related activities are carried on consistently with those obligations.

b) under international law, or under the Compliance Agreement or any other international agreement, and in relation to fishing activities by described above, that those activities are carried on consistently with those obligations

Measures by which the objectives are to be attained

The AFMA Corporate Plan 2014–2017 sets out the main goals and strategies AFMA has adopted for the next three years in pursuit of the objectives of AFMA's governing legislation, and the Annual Operational Plan describes the intended actions that are planned in order to achieve give effect to or further the goals in the following year, and performance indicators against with their performance can be assessed.

AFMA prepares an annual report that includes:

- an assessment of the extent to which the operations of the Authority during the period have contributed to the objectives set out in the annual operational plan that relates to the period; and
- particulars of:

(i) variations (if any) of the annual operational plan taking effect during that period; and

(ii) significant changes to plans of management and the introduction of new plans of management during that period; and

(iii) the effectiveness or otherwise of the operation of plans of management during that period; and

(iv) any directions given to the Authority by the Minister under section 91 during that period; and

- an evaluation of the Authority's overall performance against the performance indicators set out in the annual operational plan that came into force at the beginning of that period.

Broad categories of data collection needs

Assessments of target species
Assessment of bycatch and discards
Ecosystem
Verification/improve data collection
Licencing
Socio-economics

Specific data collection activities

✓	Logbook	✓	Dedicated research projects	✓	Owner / vessel registry
✓	CDR	✓	Interaction/bycatch studies	✓	Permits
✓	State fishery landings	✓	Survey of fishing gears	✓	Quota allocation

[10] Anon. (2014). Fisheries Administration Act 1991 No. 161, 1991 as amended, Office of Parliamentary Council, Canberra. http://www.comlaw.gov.au/Details/C2014C00521 (Accessed 6/02/2015)

√	Recreational catch estimates	√	Reference points	√	Quota trading
√	Observer / port measure	√	EMS	√	Economics
√	Age data	√	Compliance	√	Logbook Interactions
√	Industry collected length freq.	√	VMS	√	MSE
√	Fishery Independent Surveys	√	ELogs		
√	Biological / stock structure studies	√	Education		

Outputs

- AFMA Corporate Plans
- AFMA Annual Operational Plans
- Annual Reports

19.1.3. Southern and Eastern Scalefish and Shark Fishery Management Plan 2003[11]

Description

The SESSF Fisheries Management Plan is the overarching document that describes how the SESSF is to be managed. It was developed under section 17 of the Fisheries Management Act 1991, which prescribes that AFMA must "determine plans of management for all fisheries". The SESSF Fisheries Management Plan has undergone regular amendments, giving it flexibility to respond to emerging or changing issues, and its objectives are almost identical to those of the Fisheries Management Act 1991.

Objectives

a) To implement efficient and cost-effective fisheries management of the fishery on behalf of the Commonwealth;

b) to ensure that the exploitation of the resources of the fishery and the carrying on of any related activities are conducted in a manner consistent with the principles of ecologically sustainable development and the exercise of the precautionary principle and, in particular, the need to have regard to the impact of fishing activities on non-target species and the long-term sustainability of the marine environment;

c) to maximise economic efficiency in the exploitation of scalefish and shark resources within the fishery;

d) to ensure AFMA's accountability to the fishing industry and to the Australian community in the management of the resources of the fishery;

e) to reach Government targets for the recovery of the costs of AFMA in relation to the fishery;

f) to ensure, through proper conservation and management, that the living resources of the fishery are not endangered by over-exploitation;

g) to ensure the best use of the living resources of the fishery;

h) to ensure that conservation and management measures in the fishery implement Australia's obligations under international agreements that deal with fish stocks, and other relevant international agreements;

i) to ensure, as far as practicable, that measures adopted in pursuit of these objectives are not inconsistent with the preservation, conservation and protection of all whale species.

Measures by which the objectives are to be attained)

The measures by which the objectives of this Management Plan are to be attained include the following:

a) monitoring, through a structured program, the impact of fishing on fish species, any other species that are caught as by-catch, ecologically-related species and the marine environment, analysing the impacts and implementing any strategies necessary to ensure:

(i) the sustainability of those species and the marine environment; and

(ii) that by-catch limitations are not exceeded;

b) periodically checking the accuracy and consistency of information kept in relation to the fishery;

c) implementing a scheme of entitlements for people to fish in the fishery consisting of boat statutory fishing rights, quota statutory fishing rights and fishing permits;

d) determining reference points for maintaining ecologically sustainable stocks of each species taken in the fishery;

e) determining harvest strategies for quota species that will maintain their numbers above reference points, and setting TACs consistent with these harvest strategies, taking account of information

[11] AFMA (2014). Southern and Eastern Scalefish and Shark Fishery Management Plan 2003. prepared on 11 September 2014 applying from 1 May 2014 taking into account amendments up to Fisheries Legislation (Management Plans) Amendment 2013 (No. 1). http://www.comlaw.gov.au/Details/F2014C01078 (Accessed 15/10/2014)

from relevant management advisory committees and resource assessment groups;

f) setting TACs, and determining harvest strategies and reference points, for non-quota species;

g) developing, implementing and reviewing stock recovery strategies for species identified as being at or below reference points;

h) ensuring that the resource assessment group compiles regular fishery assessment reports containing the information mentioned in paragraphs (a), (b), (d), (e), (f) and (g);

i) developing, in cooperation with stakeholders, a plan to strategically address any high risks identified during ecological risk assessments;

j) developing, implementing and reviewing a strategic compliance program designed to ensure compliance with the management arrangements for the fishery;

k) issuing directions prohibiting fishing in the fishery, or part of the fishery, during specified periods, informing the holders of fishing concessions about those directions, and requiring the holders to comply with the directions;

l) developing and implementing a communication strategy in the fishery (including preparation and dissemination of regular reports regarding the status and management of the fishery) that targets fishers, other stakeholders and the Australian community;

m) consulting with relevant management advisory committees on the management of the fishery;

n) developing management arrangements that have regard to relevant international agreements;

o) preparing an annual budget, in consultation with relevant management advisory committees, of costs associated with managing the fishery, and recommending and collecting levies and fees for the fishery;

p) implementing long-term management arrangements that pursue economic efficiency for the fishery;

q) periodically evaluating whether the range and extent of management services provided by AFMA are consistent with cost-effective management.

Broad categories of data collection needs

Assessments of target species
Assessment of bycatch and discards
Ecosystem
Verification/improve data collection
Licencing
Socio-economics

Specific data collection activities

√	Logbook	√	Dedicated research projects	√	Owner / vessel registry
√	CDR	√	Interaction/bycatch studies	√	Permits
√	State fishery landings	√	Survey of fishing gears	√	Quota allocation
√	Recreational catch estimates	√	Reference points	√	Quota trading
√	Observer / port measure	√	EMS	√	Economics
√	Age data	√	Compliance	√	Logbook Interactions
√	Industry collected length freq.	√	VMS	√	MSE
√	Fishery Independent Surveys	√	ELogs		
√	Biological / stock structure studies	√	Education		

Outputs

As for the Fisheries Management Act 1991

19.1.4. Environment Protection and Biodiversity Conservation Act 1999[12]

Description

The Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act) is the Australian Government's key piece of environmental legislation. It provides a legal framework for protection and management of nationally and internationally important flora, fauna, ecological communities and heritage places. The EPBC Act is administered by the Department of the Environment (DoE).

Objectives

The objectives of the EPBC Act are to:

a) provide for the protection of the environment, especially matters of national environmental significance;
b) conserve Australian biodiversity;
c) provide a streamlined national environmental assessment and approvals process;
d) enhance the protection and management of important natural and cultural places;
e) control the international movement of plants and animals (wildlife), wildlife specimens and products made or derived from wildlife;
f) promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources;
g) recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity; and
h) promote the use of Indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge.

Measures by which the objectives are to be attained)

The DoE's Sustainable Fisheries Section is responsible for the assessment of fisheries managed under Commonwealth legislation and State export fisheries in accordance with the EPBC Act. Their primary role is to evaluate the environmental performance of fisheries, including:

- the strategic assessment of fisheries under Part 10 of the EPBC Act;
- assessments relating to impacts on protected marine species under Part 13; and
- assessments for the purpose of export approval under Part 13A.

Broad categories of data collection needs

Assessments of target species
Assessment of bycatch and discards
Ecosystem
Verification/improve data collection

Specific data collection activities

✓	Logbook	✓	Dedicated research projects		Owner / vessel registry
✓	CDR		Interaction/bycatch studies		Permits
	State fishery landings		Survey of fishing gears		Quota allocation
	Recreational catch estimates	✓	Reference points		Quota trading
	Observer / port measure		EMS	✓	Economics
	Age data		Compliance	✓	Logbook Interactions

[12] Office of Parliamentary Counsel, (2014). Environment Protection and Biodiversity Conservation Act 1999 No. 91, 1999 as amended). http://www.comlaw.gov.au/Details/C2014C00506 (Accessed 10/2/2015)

	Industry collected length freq.		VMS		MSE
	Fishery Independent Surveys		ELogs		
	Biological / stock structure studies		Education		

Outputs
Strategic assessments Declaration of an Approved Wildlife Operation Accreditation of Plan of Management for the Purposes of Part 13 Amendment of List of Exempt Native Specimens

19.1.5. Review of Commonwealth Fisheries: Legislation, Policy And Management[13]

Description
A 'root and branch' review of the legislation governing Australia's Commonwealth fisheries management arrangements was announced in September 2012. David Borthwick AO PSM submitted the review in December 2012. The scope covered the broad fisheries management policy and legislative framework to test whether it is in line with government, industry and community expectations. It identified areas requiring adjustment to better define and meet Commonwealth fisheries management objectives and it examines the underlying policy, research, legislative and regulatory framework that supports fisheries management.
Objectives
The aim of the Review was to discuss drawbacks in current fisheries management arrangements, highlight imperatives for future reform and to recommend options for government to consider.
Measures by which the objectives are to be attained
Stakeholder consultation Public submissions Review of fisheries policies
Broad categories of data collection needs
Specific data collection activities
Outputs

[13] Borthwick, D. (2012). Review Of Commonwealth Fisheries: Legislation, Policy And Management. Report to Minister for Agriculture, Fisheries and Forestry, Canberra. http://www.agriculture.gov.au/SiteCollectionDocuments/fisheries/fisheries-review/commonwealth-fisheries-management-review-report.pdf (Accessed 15/10/2014)

19.1.6. Guidelines for Implementation of the Commonwealth Fisheries Harvest Strategy Policy[14]

Description

The Guidelines for Implementation of the Commonwealth Fisheries Harvest Strategy Policy (HSP) provides a framework for the development of harvest strategies for key commercial species taken in Australia's Commonwealth fisheries. It was developed in response to a Ministerial Direction made to AFMA in December 2005 that declared that among other things, AFMA must"… take a more strategic, science-based approach to setting total allowable catch and/or effort levels in Commonwealth fisheries, consistent with a world's best practice Commonwealth Harvest Strategy Policy".

The HSP establishes outcomes to be achieved in Commonwealth fisheries and the need for strategies to be established for managing fisheries.

Objectives

The objective of this HSP is the sustainable and profitable utilisation of Australia's Commonwealth fisheries in perpetuity through the implementation of harvest strategies that maintain key commercial stocks at ecologically sustainable levels and within this context, maximise the economic returns to the Australian community.

Measures by which the objectives are to be attained

The HSP outlines a strategy for achieving its objective. This includes development of harvest strategies for key commercial stocks taken in Australia's Commonwealth fisheries that are designed to pursue maximum economic yield from the fishery and ensure those stocks remain above levels at which the risk to the stock is unacceptably high.

Harvest strategies will include a limit and target reference points, indicators and performance measures. The technical process in developing a harvest strategy is described as including: policy setting, management controls, species to be considered, data available, analysis and assessment, development of reference points, operationalize and allocate Tiers if appropriate, develop initial options for harvest control rule, develop full harvest strategy including monitoring, assessment and harvest control rule, qualitative evaluation, full management strategy evaluation and finally, implementation.

Broad categories of data collection needs

Assessment of target species
Verification/improve data collection
Socio-economics

Specific data collection activities

✓	Logbook		Dedicated research projects		Owner / vessel registry
✓	CDR		Interaction/bycatch studies		Permits
✓	State fishery landings		Survey of fishing gears		Quota allocation
✓	Recreational catch estimates	✓	Reference points		Quota trading
✓	Observer / port measure		EMS	✓	Economics
✓	Age data		Compliance		Logbook Interactions
✓	Industry collected length freq.		VMS	✓	MSE
✓	Fishery Independent Surveys	✓	ELogs		

[14] DAFF. (2007). Guidelines for Implementation of the Commonwealth Fisheries Harvest Strategy Policy. DAFF, Canberra. http://www.agriculture.gov.au/SiteCollectionDocuments/fisheries/domestic/hsp.pdf (Accessed 15/10/2014)

✓	Biological / stock structure studies		Education		

Outputs
• Development of harvest strategies for key fish stocks • Annual Report on implementation of the HSP

19.1.7. Final report on the review of the Commonwealth Fisheries Harvest Strategy Policy and Guidelines [15]

Description
The HSP included the need for a review and report delivered to the Minister for Fisheries, Forestry and Conservation and the Minister for Environment and Water Resources within five years of commencement. That review was undertaken by DAFF in collaboration with other agencies, and in consultation with stakeholders, with the final report published in May 2013. The report describes outcomes of a review of the HSP and its guidelines, and found that the HSP and guidelines remain a solid foundation for Commonwealth fisheries management. It recommended that some areas of the HSP and guidelines be refined and updated to capture new developments and address any weaknesses to ensure they continue to allow the Government to pursue fisheries management objectives in a way that represents world's best practice.
Objectives
Evaluate: • the role and functioning of the policy in relation to the broader legislative and policy environment; • the appropriateness and adequacy of the guidelines; and • the implementation of the policy.
Measures by which the objectives are to be attained
Commissioned research • Implementation review – technical aspects of the implementation of the policy and includes information on whether fishery management actions and decisions have been consistent with the policy, challenges encountered in implementing the policy and changes in the status of fisheries that might be a result of the policy's implementation. The review also highlights the improvements in the status of Commonwealth fish stocks since the late 2000s. • Literature review of fisheries best practice – desktop study of international best practice harvest strategy policy approaches and settings. • Technical review of HSP – The CSIRO review of the technical aspects of the harvest strategy policy considered matters such as reference points and life history characteristics; buffers and meta-rules; data-poor fisheries and the tiered approach to harvest strategies; total allowable catches; rebuilding strategies and spatial management. • Technical reviews for the HSP: economic issues – economic definitions and understanding in the harvest strategy policy; challenges to implementing maximum economic yield; data-poor species; multi-species fisheries; variable stocks; market power and internationally managed fisheries. • Risk-based approaches, reference points and decision rules – considers the principles, framework and processes of risk management as well as risk-based approaches to bycatch and byproduct management. It also explores reference points and decision rules for bycatch and byproduct; low information analytical approaches to bycatch and byproduct assessment; and monitoring and performance evaluation. • Technical overview report – identifies technical areas where the harvest strategy policy might be improved. It synthesises the conclusions of the technical reports mentioned previously, with other studies, to provide evidence to support possible changes to the policy.
Broad categories of data collection needs
Assessment of target species Assessment of bycatch and discards Ecosystems

[15] DAFF. (2013). Final report on the review of the Commonwealth Fisheries Harvest Strategy Policy and Guidelines. DAFF, Canberra. http://www.agriculture.gov.au/SiteCollectionDocuments/fisheries/environment/bycatch/report-harvest-strategy.pdf (Accessed 15/10/2014)

Socio - economics					
Specific data collection activities					
✓	Logbook		Dedicated research projects		Owner / vessel registry
✓	CDR		Interaction/bycatch studies		Permits
✓	State fishery landings		Survey of fishing gears		Quota allocation
✓	Recreational catch estimates	✓	Reference points		Quota trading
✓	Observer / port measure		EMS	✓	Economics
✓	Age data		Compliance		Logbook Interactions
✓	Industry collected length freq.		VMS	✓	MSE
✓	Fishery Independent Surveys	✓	ELogs		
✓	Biological / stock structure studies		Education		
Outputs					
• Final report					

19.1.8. Harvest Strategy Framework for the Southern and Eastern Scalefish and Shark Fishery[16]

Description

The Harvest Strategy Framework for the Southern and Eastern Scalefish and Shark Fishery (HSF) was developed in accordance with the HSP, and sets out the management actions necessary to achieve defined biological and economic objectives, and describes the indicators used for monitoring the condition of stocks, the types of assessments conducted and the rules applied to determine the recommended total allowable catches.

Objectives

The objectives of the HSF include:

Biological

a) to maintain stocks at (on average), or return to, a target biomass point B_{TARG} or equivalent proxy (e.g. F_{TARG} or $CPUE_{TARG}$) equal to the stock size that aims to maximise net economic returns for the fishery as a whole;

b) to maintain stocks above the limit biomass level, or an appropriate proxy, at least 90% of the time;

c) to progressively reduce the level of fishing if a stock moves below B_{MSY} and towards B_{LIM} (or an appropriate proxy);

d) to implement rebuilding strategies, no-targeting and bycatch TACs if a stock moves below B_{LIM} (or an appropriate proxy).

e) to ensure the sustainability of fisheries resources, including consideration of the individual fishery circumstances and individual species or stock characteristics, when developing a management approach;

Socio-economic

f) to maintain stocks at (on average), or return to, a target biomass point B_{TARG} equal to the stock size that aims to maximise net economic returns for the fishery as a whole;

g) to maximise the profitability of the fishing industry and the net economic returns to the Australian community;

h) to minimise costs to the fishing industry, including consideration of the impacts on the industry of large or small changes in TACs, and ensuring that management strategies are, as far as possible, equitably distributed among industry sectors; and

Ecosystem

i) to be consistent with the principles of ecologically sustainable development, including the conservation of biological diversity, and the adoption of a precautionary risk approach.

Measures by which the objectives are to be attained

Key activities required to achieve the objectives can be broken into two categories: Monitoring and Reference points and decision rules.

Monitoring

The HSF describes three different methods for monitoring biological and economic conditions of the fishery: logbooks and catch records, the observer program and fishery independent surveys.

Reference points and decision rules

Activities undertaken relating to reference points and decision rules include stock assessments, estimation of B_{MEY} (if possible), calculation of Commonwealth TACs from Recommended Biological Catches (RBCs),

[16] AFMA. (2014). Harvest Strategy Framework for the Southern and Eastern Scalefish and Shark Fishery. 2009 – amended February 2014, AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2012/07/SESSF-Harvest-Strategy-Framework-2014-final.pdf (Accessed 15/10/2014)

evaluation of reference points and decision rules through MSE.

Broad categories of data collection needs

Assessment of target species
Verification/improve data collection
Socio-economics

Specific data collection activities

✓	Logbook		Dedicated research projects		Owner / vessel registry
✓	CDR		Interaction/bycatch studies		Permits
✓	State fishery landings		Survey of fishing gears		Quota allocation
✓	Recreational catch estimates	✓	Reference points		Quota trading
✓	Observer / port measure		EMS	✓	Economics
✓	Age data		Compliance		Logbook Interactions
✓	Industry collected length freq.		VMS	✓	MSE
✓	Fishery Independent Surveys	✓	ELogs		
✓	Biological / stock structure studies		Education		

Outputs

- Final report

19.1.9. The National Policy on Fisheries Bycatch [17]

Description

The National Policy on Fisheries Bycatch was developed "to ensure that direct and indirect impacts on aquatic systems are taken into account in the development and implementation of fisheries management". This is required by a number of national and international requirements including the Commonwealth Fisheries
Management Act 1991 and the United Nations Convention on the Law of the Sea. The policy provides a broad, strategic approach in addressing bycatch from fishing in Australian waters.

Objectives

The over-arching objective of the Policy is to ensure that bycatch species and populations are maintained at sustainable levels.

The sub-objectives are:

1. To reduce bycatch;
2. To improve protection for vulnerable/threatened species;
3. To minimise adverse impacts of fishing on the aquatic environment.

Measures by which the objectives are to be attained

The policy recommends a number of strategies for addressing bycatch including:

- prioritization of critical bycatch issues and resourcing requirements;
- development of codes of practice to minimise bycatch;
- fisheries adjustment mechanisms
- development of management plans, legislative arrangements and bycatch action plans
- education and training programs
- economic incentives or adjustment arrangements
- cooperative bycatch management arrangements between jurisdictions
- research into identifying the impacts of fishing on bycatch, by-product and other species,
- mitigation techniques and use of bycatch species
- regulation for appropriate gear design or fishing practice
- enhancement of the quality and quantity of fisheries data collection

Broad categories of data collection needs

Assessment of bycatch and discards
Verification/improve data collection
Socio-economics

Specific data collection activities

✓	Logbook	✓	Dedicated research projects		Owner / vessel registry
	CDR	✓	Interaction/bycatch studies		Permits
	State fishery landings	✓	Survey of fishing gears		Quota allocation
✓	Recreational catch estimates		Reference points		Quota trading
✓	Observer / port measure	✓	EMS	✓	Economics

[17] DAFF. (1999). The National Policy on Fisheries Bycatch was endorsed by the Ministerial Council on Forestry, Fisheries and Aquaculture in April 1999, Canberra. http://www.agriculture.gov.au/SiteCollectionDocuments/fisheries/environment/bycatch/national-bycatch-policy-1999.pdf (Accessed 18/08/2016)

	Age data	✓	Compliance	✓	Logbook Interactions
	Industry collected length freq.	✓	VMS	✓	MSE
✓	Fishery Independent Surveys	✓	ELogs		
✓	Biological / stock structure studies	✓	Education		

Outputs

- Fisheries management plans
- Others described under "Measures by which the objectives are to be attained"

19.1.10. Report on the review of the Commonwealth Policy on Fisheries Bycatch [18]
Description
The review of the Commonwealth Policy on Fisheries Bycatch 2000 was announced in March 2012, the Minister for Agriculture, Fisheries and Forestry, Senator the Hon. Joe Ludwig. The review was largely driven by the age of the policy, the implementation of the EPBC Act, the release of the Commonwealth Fisheries Harvest Strategy Policy and Guidelines (harvest strategy policy), and the range of bycatch management actions taken in Commonwealth fisheries since the release of the policy. The review examined the context and purpose of the bycatch policy, its interaction with the harvest strategy policy, definitions of bycatch and other elements of catch, managing data-poor species, different assessment and management approaches, reference points, decision rules and risk-based approaches, and it considered cumulative effects from multiple fisheries.
Objectives
The terms of reference for the review state the objective as being: *To improve the management of bycatch in Commonwealth fisheries by developing an integrated policy and implementation framework that links with the harvest strategy policy and supports current environmental and fisheries legislative requirements.* *The objective of the review is also to develop a framework that contributes to greater management certainty for fishers ensures the achievement of the environmental outcomes and increases confidence by the retail sector, consumers and the general public about the sustainability of Australian seafood.*
Measures by which the objectives are to be attained
The review provided a number of improvements that could be made to the bycatch policy and its implementation including: • Explicit recognition that as part of an ecosystem-based approach, encompassing the fishing industry's impact on the entire marine environment, bycatch policy forms an essential element of the overall fisheries policy approach by addressing all interactions between living creatures and fishing operations. • A continuous and comprehensive classification scheme that ensures all elements of the marine environment are addressed either through the bycatch policy, harvest strategy policy or an ecosystems policy/approach. • The defining of catch components, especially commercial species, bycatch, byproduct and discards. • Recognition that the resources to address bycatch policy are necessarily constrained, and a risk-based approach is unavoidable. Recognition that this is particularly so in fisheries where the costs of management are cost recovered from the fishers. This further recognises use of the AFMA ecological risk assessment and risk management framework and enhancing this in a revised policy and associated guidelines. • Use of quantitative reference points and performance measures encourages consistency of treatment across fisheries and potentially jurisdictions and places science at the forefront of the decision-making process. • Assessment of the cumulative impact on species to be assessed to the extent possible and practicable. Recognition that cumulative assessments and subsequent management responses are challenged by cross-jurisdictional management. • Establishment of detailed implementation guidelines to aid consistent implementation of the policy. • Recognition that initiatives that increase transparency and public confidence in the decision-making processes associated with Commonwealth fisheries will benefit the industry (by an improved consumer response) and potentially increase the resources available for fisheries management.

[18] DAFF (2013). Report on the review of the Commonwealth Policy on Fisheries Bycatch. Department of Agriculture, Fisheries and Forestry, Canberra. http://www.agriculture.gov.au/SiteCollectionDocuments/fisheries/environment/bycatch/fisheries-bycatch27may13.doc (Accessed 18/08/2016)

- Recognition that a major element of the bycatch policy is monitoring the effectiveness of different initiatives and the need to address the high cost of collecting reliable performance data.
- Species protected under the EPBC Act to be managed differently to other bycatch species.

Broad categories of data collection needs

Assessment of bycatch and discards
Verification/improve data collection

Specific data collection activities

✓	Logbook	✓	Dedicated research projects		Owner / vessel registry
	CDR	✓	Interaction/bycatch studies		Permits
	State fishery landings	✓	Survey of fishing gears		Quota allocation
✓	Recreational catch estimates	✓	Reference points		Quota trading
✓	Observer / port measure	✓	EMS	✓	Economics
	Age data	✓	Compliance	✓	Logbook Interactions
	Industry collected length freq.	✓	VMS	✓	MSE
✓	Fishery Independent Surveys	✓	ELogs		
✓	Biological / stock structure studies	✓	Education		

Outputs

- An implemented revises bycatch policy

19.1.11. AFMA's Program for Addressing Bycatch and Discarding in Commonwealth Fisheries: an Implementation Strategy [19]

Description

The AFMA bycatch and discarding program was established in 2007 in response to the 2005 Ministerial Direction that called for AFMA to:

- manage the broader environmental impacts of fishing, including protected species;
- minimise the incentives for discarding by ensuring it is factored into the setting of total allowable catch (TAC) levels; and
- enhance the monitoring of fishing activity, through increased use of vessel monitoring systems (VMS) with daily reporting, on-board cameras and improved observer coverage.

AFMA's Program for Addressing Bycatch and Discarding in Commonwealth Fisheries: an Implementation Strategy provides the background to the legislative and policy requirements placed on Commonwealth fisheries with respect to bycatch and discarding of target / quota species (Stream 1), and sets out how AFMA will pursue responsibilities for addressing bycatch and discarding of target / quota species in Commonwealth fisheries through the bycatch and discarding program (Stream 2).

Objectives

The program was aimed at assisting fisheries in addressing bycatch and discard issues in a focussed and cost effective way. The initial directions of the program were to:

1. deal with high risk and threatened, endangered and protected (TEP) species; and
2. to minimise discarding of target / quota species to as close to zero as practically possible.

Measures by which the objectives are to be attained

Actions to be undertaken to address each stream are:

Stream 1

1. Bycatch working groups or subcommittees developing, and fisheries implementing, a bycatch and discarding work plan to avoid interactions with TEP species and mitigate high ecological risk bycatch as determined through ERAs and residual risk analysis. Work plans will be developed and commence during 2008 and will include annual milestones which are to be measured through a fishery monitoring program.
2. Ensuring there is an adequate long-term monitoring program covering all aspects of bycatch and interactions with TEP species. Fishery management frameworks must include risk and/or stock assessments and a capacity to respond to new information about bycatch in the fishery.
3. In fisheries with high bycatch volume, work plans must include a longer-term program for progressive reductions in overall bycatch.

Stream 2

1. Bycatch working groups or subcommittees developing, and fisheries implementing, a bycatch and discarding work plan that includes incentives and measures for fishers to avoid or reduce discarding and address the common drivers of discarding. Work plans will be developed and commence during 2008 and will include annual milestones for discard reduction which are to be measured through a fishery monitoring program.
2. Fisheries must ensure their monitoring program provides an annual estimate of the discard rate for each target / quota species in a form that can be taken into account in the harvest strategy (refer to the Commonwealth Harvest Strategy Policy 2007).

Broad categories of data collection needs

Assessment of bycatch and discards

[19] AFMA. (2008). AFMA's Program for Addressing Bycatch and Discarding in Commonwealth Fisheries: an Implementation Strategy. AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2010/06/is_env_bycatch-prog_feb08_20080417.pdf (Accessed 20/10/2014)

Verification/improve data collection
Ecosystems

Specific data collection activities

✓	Logbook	✓	Dedicated research projects		Owner / vessel registry
✓	CDR	✓	Interaction/bycatch studies		Permits
	State fishery landings		Survey of fishing gears		Quota allocation
	Recreational catch estimates		Reference points		Quota trading
✓	Observer / port measure	✓	EMS		Economics
	Age data	✓	Compliance	✓	Logbook Interactions
	Industry collected length freq.		VMS		MSE
	Fishery Independent Surveys	✓	ELogs		
✓	Biological / stock structure studies	✓	Education		

Outputs

- Bycatch and discarding work plans for each fishery

19.1.12. Threat Abatement Plan 2014 for the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations [20]
Description
The incidental catch (or bycatch) of seabirds during oceanic longline fishing operations was listed as a key threatening process in 1995 under the *Endangered Species Protection Act 1992*. In response, a Threat Abatement Plan (TAP) was implemented in 1998, has subsequently been updated in 2006 and 2011. The TAP only applies to fishing using longlines in the Australian Fishing Zone, and this includes the hook sub-sector of the GHaTS. The TAP sets out a goal and objective, actions required to achieve the objective including monitoring and analysis, performance measures and responsibilities.
Objectives
The goal of the TAP is to achieve a zero bycatch of seabirds, especially threatened albatross and petrel species, in all longline fisheries. The objective of the TAP is to continue to significantly reduce the seabird bycatch and bycatch rate during oceanic longline fishing operations in the Australian Fishing Zone.
Measures by which the objectives are to be attained
The objective of this threat abatement plan is to be achieved through five key actions: 1. **Mitigation** – effective measures will continue to be applied, both through legislative frameworks and fishing practices, to ensure seabird bycatch and bycatch rates are continually reduced, recognising the importance of other factors such as safety, practicality and the characteristics of the fishery. Specific mitigation measures are specified for each fishery. 2. **Education** – results from data analysis will continue to be communicated throughout the community, stakeholder groups and international forums, and programs will continue or be established to provide information and education to longline operators. 3. **International initiatives** – global adoption of seabird by-catch mitigation trigger and other limits, and effective bycatch and other threat mitigation methods will continue to be pursued through international conservation and fisheries management forums. 4. **Research and Development and Uptake** – research into new and existing mitigation measures and their development, trial, adoption and assessment will continue to be supported including, as relevant, research into whether mitigation measures are ineffective, through the granting of individual permits and the potential approval of new measures to apply throughout a fishery. 5. **Innovation** – innovation in 'bird friendly' fishing measures and devices will continue to be encouraged. Data collection and analysis are other key actions of the TAP. Data will be collected and analysed to assess the performance of the TAP including mitigation measures and to improve knowledge of seabird-longline interactions. Specific data collection activities listed include reporting / validation of interactions through logbooks, observers and EMS, retention of dead seabirds or tissue samples, reporting banded birds, analysis and reporting of interaction data and consideration of impacts of actions described by the TAP on other marine species.
Broad categories of data collection needs
Assessment of bycatch and discards Ecosystem Verification/improve data collection
Specific data collection activities

[20] Commonwealth of Australia (2014). Threat Abatement Plan 2014 for the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations, Department of the Environment, Canberra. http://www.antarctica.gov.au/__data/assets/pdf_file/0017/21509/Threat-Abatement-Plan-2014.pdf (Accessed 12/03/2015)

✓	Logbook	✓	Dedicated research projects		Owner / vessel registry
	CDR	✓	Interaction/bycatch studies		Permits
	State fishery landings	✓	Survey of fishing gears		Quota allocation
	Recreational catch estimates		Reference points		Quota trading
✓	Observer / port measure	✓	EMS		Economics
	Age data	✓	Compliance	✓	Logbook Interactions
	Industry collected length freq.	✓	VMS		MSE
	Fishery Independent Surveys	✓	ELogs		
	Biological / stock structure studies	✓	Education		

Outputs

- Management responses as required (AFMA)
- Annual report on progress in achieving objective of TAP and implementation of actions (AFMA and DoE)
- Extension and training programs for fishers where appropriate (AFMA)
- Annual compliance reports including assessment of implementation of mitigation measures and incidents of non-reporting of interactions or mortalities (AFMA)
- Annual reporting of progress of implementing TAP and promotion of TAP to international conservation forums (DoE)
- Annual review of interaction data (AFMA and DoE)

19.1.13. Blue Warehou (*Seriolella brama*) Stock Rebuilding Strategy 2008 (Revised April 2012)[21] and draft Blue Warehou (*Seriolella brama*) Stock Rebuilding Strategy Revised 2014[22]

Description
Blue Warehou is assessed and managed as two separate stocks, eastern and western. Between 1992 and 1999, the classification of stock status of Blue Warehou fluctuated between uncertain and not overfished / not overfishing, but since 2000 has fluctuated between uncertain and overfished / overfishing. Much of the uncertainly in assessments is likely to have been caused by the close relationship between biomass and recruitment, and lack of available and representative data which may be attributed to the patchy distribution of the stock, schooling of the fish by size, reduced catch rates as a result of a reduced TAC and poor sampling in some years. In accordance with the Commonwealth Harvest Strategy Policy and pursuant of the objectives set out in the Fisheries Management Act 1991, the Blue Warehou Stock Rebuilding Strategy was implemented in 2008 to rebuild stocks to the target biomass level. A 2012 revision updated the reporting requirements due to total allowable catch changes that expanded to include the non-trawl sectors of the SESSF. The development and implementation of this rebuilding strategy is also a condition of the SESSF Wildlife Trade Operation (WTO) accreditation under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). The Blue Warehou Stock Rebuilding Strategy includes objectives, a description of management arrangements to achieve the objectives, monitoring recovery and performance measures and a schedule of review. The Blue Warehou Stock Rebuilding Strategy was again revised during 2014, and the draft is currently in consultation phase. This revised draft is more comprehensive than the 2008 document, and includes sections on management actions to achieve the objectives, monitoring and evaluation and stock assessments and data collection.
Objectives
2008 Stock Rebuilding Strategy 1. To rebuild Blue Warehou (east and west) stocks in the area of the SESSF to the limit reference biomass level (B_{20}) within a biologically reasonable time frame; being one mean generation time, approximately 6.3 years. 2. Having reached B_{20}, rebuild Blue Warehou (east and west) stocks in the area of the SESSF to the initial target (maximum sustainable yield) biomass level (B40) within a biologically reasonable time frame, for example 10 years, plus one mean generation time or three times the mean generation time, whichever is the shorter, being approximately 16 to 18 years. 3. Once the initial target biomass level is reached, use appropriate modelling to determine the final target (maximum economic yield) biomass for Blue Warehou and a trajectory for the rebuilding of the stock to that point. Once Blue Warehou stocks have recovered above B_{40}, management measures will remain in place to ensure the stocks remain stable above this level in accordance with the HSP. 2014 Stock Rebuilding Strategy 1. To rebuild Blue Warehou (east and west) stocks in the area of the SESSF to or above the default limit reference biomass point (B_{LIM}) of 20% of the unfished spawning biomass within a biologically reasonable time frame; one mean generation time plus 10 years (approximately 16 years). That is, to reach or exceed B_{LIM} by no later than 2024.

[21] AFMA (2012). Blue Warehou (*Rexea solandri*) Stock Rebuilding Strategy 2008. AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2010/07/Blue-Warehou-Stock-Rebuilding-Strategy-FINAL-April-2012.pdf (Accessed 15/10/2014)

[22] AFMA (2014). Draft Blue Warehou (*Rexea solandri*) Stock Rebuilding Strategy Revised 2014, AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2014/10/draft-blue-warehou-rebuilding-strategy-26.9.14.pdf (Accessed 16/10/2014)

2. Having reached B_{LIM}, rebuild Blue Warehou (east and west) stocks in the area of the SESSF to the default maximum sustainable yield biomass level of 40% of the unfished spawning biomass (B_{MSY}) using the harvest control rules outlined in the SESSF Harvest Strategy Framework.
3. Once B_{MSY} is reached, pursue the biomass level which aims to maximise net economic returns, currently 48% of unfished spawning biomass (B_{MEY}).

Measures by which the objectives are to be attained

The Blue Warehou Stock Rebuilding Strategy 2008 includes detailed descriptions of management arrangement to be implemented to achieve the objectives including current (then) management arrangements, issues with those arrangements and future management arrangements. There is also a section on monitoring recovery and performance measures, and the observer monitoring program. Aspects of the rebuilding plan and data requirements for the 2008 document are described below:

a) Set incidental catch TAC, and undertake further analysis of incidental catch that may cause the TAC to be reduced in future years. TAC based analysis of logbook data looking at species associations;
b) Limited entry;
c) Adoption of more selective gear;
d) Implementation, compliance and review of spatial and temporal closures (a voluntary closure has been in place since 2008 to protect historic spawning grounds);
e) Monitor catches in relation to trigger limits, work with industry to improve reporting of discards in logbooks and monitor discards through the observer program;
f) Measure relative abundance through fishery independent surveys;
g) Improved data collection through industry collected length frequencies to supplement data from observer program;
h) Develop industry code of conduct and reinforce through education;
i) Update Tier 4 assessment annually.

Aspects of the rebuilding plan and data requirements for the 2014 document are described below

a) Set and regularly review incidental catch TAC based on analysis of logbook data estimating levels of unavoidable incidental catch. If an increase in targeting is identified, TAC may be decreased, move on provisions introduced or spatial closures implemented;
b) Limited entry;
c) Trawl gear selectivity – Minimum mesh size was increased to 90 mm during 2006 and in most cases a bycatch reduction device must be used. For gillnets the mesh size must be between 15 cm and 16.5 cm;
d) Monitor and enforce fishing closures;
e) Catch triggers – TAC is split between stocks, and there are reporting arrangements in place to track cumulative catch during the fishing year, and result in the cessation of all Blue Warehou in that zone;
f) Increased data collection through fishery independent surveys, the observer program, industry collected data and potentially EMS.

Broad categories of data collection needs

Assessments of target species
Assessment of bycatch and discards
Licencing / quota
Verification/improve data collection
Ecosystem

Specific data collection activities

✓	Logbook		Dedicated research projects	✓	Owner / vessel registry
✓	CDR		Interaction/bycatch studies	✓	Permits
✓	State fishery landings	✓	Survey of fishing gears	✓	Quota allocation

	Recreational catch estimates	√	Reference points		Quota trading
√	Observer / port measure	√	EMS		Economics
√	Age data	√	Compliance		Logbook Interactions
√	Industry collected length freq.	√	VMS		MSE
√	Fishery Independent Surveys	√	ELogs		
	Biological / stock structure studies	√	Education		

Outputs
• ShelfRAG will annually review the status of Blue Warehou stocks and performance against the objectives of the Strategy • AFMA will report annually on stock status and performance against the goals of the rebuilding strategy to DoE • AFMA will also report on observer coverage and compliance with the rebuilding strategy to DEWHA

19.1.14. Commonwealth Trawl Sector (Otter Board Trawl & Danish Seine) Bycatch and Discarding Workplan [23]

Description
Pursuant of the Fisheries Management Act 1991, and in accordance with the SESSF Management Plan 2003, AFMA has developed and implemented a Bycatch and Discarding Workplan for the CTS of the SESSF. Bycatch and Discarding Workplans ensure that information is gathered about the impact of the fishery on bycatch species, and that all reasonable steps are taken to avoid incidental interactions with TEP species, and that the ecological impacts of fishing on habitats are minimised. The CTS Bycatch and Discarding Workplan covers both otter trawl and Danish seine vessels. The workplan was developed in consultation with SEMAC and SETFIA, and with consideration of ERA high risk species, general bycatch issues and progress against the previous workplan. It briefly describes existing measures to reduce bycatch, and provides action items that are to be undertaken during 2014–16.
Objectives
The CTS Bycatch and Discarding Workplan was developed to support the overall objectives of the Southern and Eastern Scalefish and Shark Ecological Risk Management (ERM) Strategy. They are to: 1. reduce the number of high risk species as assessed through AFMA's Ecological Risk Assessment process; 2. avoid interactions with species listed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act); 3. reduce discarding of target and non-target species to as close to zero as practically possible; and 4. minimise overall bycatch in the fishery over the long-term.
Measures by which the objectives are to be attained
The CTS Bycatch and Discarding Workplan lists specific action items to be undertaken during 2014–16. They are: a) continue the shortened codend investigation, which is an industry managed project comparing seal interaction rates between nets of different lengths; b) review all vessel Seabird Management Plans across the fishery and continue industry managed project educating skippers and crews on deploying seabird mitigation measures; c) develop and test additional seabird mitigation devices through an industry managed project; d) deliver an online learning module for seabird bycatch issues and mitigation methods, shark & ray bycatch issues and mitigation methods and bycatch reporting through an industry managed education project; e) distribute seabird and high risk species identification guides to all vessels in the CTS through industry and AFMA managed education projects; f) develop mitigation devices for dogfish species when fishing for Royal Red Prawns through an industry managed project; g) develop and distribute chondrichthyan (sharks and rays) best handling practices guide to all operators in the CTS through an AFMA managed education project; h) assess trends in catch of high risk bycatch species through an AFMA managed project analysing logbook and observer data.
Broad categories of data collection needs
Assessment of bycatch and discards Verification/improve data collection
Specific data collection activities

[23] AFMA. (2014). Commonwealth Trawl Sector (Otter Board Trawl & Danish Seine) Bycatch And Discarding Workplan. AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2010/06/CTS-Bycatch-and-Discarding-Workplan-2014-2016.pdf (Accessed 15/10/2014)

√	Logbook	√	Dedicated research projects		Owner / vessel registry
√	CDR	√	Interaction/bycatch studies		Permits
	State fishery landings		Survey of fishing gears		Quota allocation
	Recreational catch estimates		Reference points		Quota trading
√	Observer / port measure		EMS		Economics
	Age data	√	Compliance	√	Logbook Interactions
	Industry collected length freq.		VMS		MSE
	Fishery Independent Surveys		ELogs		
	Biological / stock structure studies	√	Education		

Outputs

- Action item reports
- Online learning modules
- Identification guides
- Shark and Ray handling guide
- Regular reviews
- At the end of the two year period the outputs of this Workplan will be reported to the Department of Environment and a new Workplan will be developed and implemented.

19.1.15. Great Australian Bight Trawl Fishery Bycatch And Discarding Workplan [24]

Description

Pursuant of the Fisheries Management Act 1991, and in accordance with the SESSF Management Plan 2003, AFMA has developed and implemented a Bycatch and Discarding Workplan for the Great Australian Bight Trawl Fishery (GABTF) sector of the SESSF. The GABTF Bycatch and Discarding Workplan covers vessels operating in Commonwealth waters adjacent to Western Australia east of cape Leeuwin and South Australia west of Cape Jervis.

The workplan briefly describes existing measures to reduce bycatch, and provides action items that are to be undertaken during 1 November 2010 – 31 October 2012. An updated bycatch and discarding workplan has been developed, but has not yet been approved for release.

Objectives

The objective of the GABTF Bycatch and Discarding workplan is to develop strategies that will:

1. respond to high ecological risks assessed through the Australian Fisheries Management Authorities (AFMA's) Ecological Risk;
2. assessment for the Effect of Fishing (ERAEF) and other assessment processes;
3. avoid interactions with species listed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act);
4. reduce discarding of target species to as close to zero as practically possible;
5. minimise overall bycatch in the fishery over the long-term; and
6. improve fishing practices.

Measures by which the objectives are to be attained

The GABTF Bycatch and Discarding Workplan lists specific action items to be undertaken during the 12 months following implementation. They are:

a) analyse combined ISMP and industry recorded bycatch and discard rates using logbook and observer data;
b) evaluate of the effectiveness of Thyberon No 15 boards (flying boards) through field trials;
c) conduct further trials of net configurations to reduce bycatch;
d) analyse combined observer and industry recorded bycatch and discard data on Sharks, Stingarees, Rays and Skates to understand the spatial and temporal catches;
e) commission a study to gain a more comprehensive understanding of the biology and population dynamics of latchets and leatherjacket;
f) Develop projects to better utilise major bycatch species in the fishery.

An additional ongoing project is for "further investigations of gear modifications".

Broad categories of data collection needs

Assessment of bycatch and discards

Specific data collection activities

✓	Logbook	✓	Dedicated research projects		Owner / vessel registry
✓	CDR	✓	Interaction/bycatch studies		Permits
	State fishery landings		Survey of fishing gears		Quota allocation
	Recreational catch estimates		Reference points		Quota trading

[24] AFMA. (2010). Great Australian Bight Trawl Fishery Bycatch And Discarding Workplan. AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2010/06/GABTF-Workplan-1-Nov-2010-to-31-Oct-2012.pdf (Accessed 15/10/2014)

✓	Observer / port measure		EMS		Economics
	Age data		Compliance	✓	Logbook Interactions
	Industry collected length freq.		VMS		MSE
	Fishery Independent Surveys	✓	ELogs		
✓	Biological / stock structure studies		Education		

Outputs
• Action item reports • Regular reviews

19.1.16. Automatic Longline Fishery Bycatch And Discarding Workplan [25]

Description

Pursuant of the Fisheries Management Act 1991, and in accordance with the SESSF Management Plan 2003, AFMA has developed and implemented a Bycatch and Discarding Workplan for the Automatic Longline sector of the SESSF. The Automatic Longline Fishery Bycatch and Discarding Workplan covers SESSF vessels that use automatic longline gear.

The workplan covers the period 1 July 2009 – 30 June 2011, briefly describes existing measures to reduce bycatch, and provides action items that are to be undertaken during the 12 months after implementation. An updated bycatch and discarding workplan has been developed, but has not yet been approved for release.

Objectives

In line with Government policy to minimise bycatch and discarding in all commercial fisheries, the Automatic Longline Bycatch and Discarding Workplan address these issues with the key priorities being to;

1. address high ecological risk species identified through AFMA's ERA process;
2. address interactions with species listed as threatened, endangered or protected (TEP) under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act);
3. reduce discarding of target species to as close to zero as practically possible; and
4. quantify and minimise overall levels of bycatch in the fishery.

Measures by which the objectives are to be attained

The Automatic Longline Bycatch and Discarding Workplan lists specific action items to be undertaken during the 12 months following implementation, with a new list of actions to be developed for the second 12 month period. They are:

a) redesign observer program sampling through analysis of logbook and observer data to improve coverage for bycatch and high risk species;
b) develop a code of conduct to improve handling practices of high risk species including rays and skates through a joint industry and AFMA project;
c) Improve species identification and reporting of gulper sharks through workshop and ID booklets;
d) undertake a gulper shark population survey of the upper slope habitat from Tas to Qld including tagging / movement studies, to improve understanding of spatial distribution and abundance of gulper shark.

An additional potential future project was a tag and release study for gulper sharks.

Broad categories of data collection needs

Assessment of bycatch and discards
Verification/improve data collection
Ecosystems

Specific data collection activities

✓	Logbook	✓	Dedicated research projects		Owner / vessel registry
✓	CDR	✓	Interaction/bycatch studies		Permits
	State fishery landings		Survey of fishing gears		Quota allocation
	Recreational catch estimates	✓	Reference points		Quota trading
✓	Observer / port measure	✓	EMS	✓	Economics

[25] AFMA. (2009). Automatic Longline Fishery Bycatch And Discarding Workplan. AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2010/06/all_bwp_2009_06_16.pdf (Accessed 15/10/2014)

	Age data	✓	Compliance	✓	Logbook Interactions
	Industry collected length freq.	✓	VMS		MSE
	Fishery Independent Surveys	✓	ELogs	✓	ERA
✓	Biological / stock structure studies	✓	Education		

Outputs

- Progress on the actions will be reported at 6 and 12 months
- Action item reports
- Code of conduct
- ID kit for gulper sharks

19.1.17. Shark Gillnet Fishery Bycatch And Discarding Workplan [26]

Description
Pursuant of the Fisheries Management Act 1991, and in accordance with the SESSF Management Plan 2003, AFMA has developed and implemented a Bycatch and Discarding Workplan for the Shark Gillnet sector of the SESSF. The Shark Gillnet Fishery Bycatch and Discarding Workplan covers shark gillnet vessels operating in Commonwealth waters adjacent to Western Australia east of cape Leeuwin and South Australia west of Cape Jervis. The workplan covers the period 1 July 2009 – 30 June 2011, briefly describes existing measures to reduce bycatch, and provides action items that are to be undertaken during the 12 months after implementation. An updated bycatch and discarding workplan has been developed, but has not yet been approved for release.
Objectives
In line with Government policy to minimise bycatch and discarding in all commercial fisheries, the key objectives of the Shark Gillnet Fishery Bycatch and Discarding Work Plan for calendar years 2009–11 are to: 1. respond to key high risk species and take steps to increase the knowledge of all high risk species and their interactions with the fishery; 2. develop a longer-term response plan for all remaining high risk species based on scientific advice; 3. develop measures to mitigate interactions with TEP species; and 4. ensure through independent monitoring that robust estimates of discarding are made and used in the harvest strategy for the GHaTS.
Measures by which the objectives are to be attained
The Shark Gillnet Fishery Bycatch and Discarding Workplan lists specific action items to be undertaken during the 12 months following implementation, with a new list of actions to be developed for the second 12 month period. They are: a) conduct the Southern Shark Survey, a fishery independent survey to obtain an index of abundance, bycatch species composition and estimates of post capture mortality rates; b) development of a low cost method of monitoring all species caught in the gillnet sector such as the industry first shot survey; c) analyse the spatial overlap of sea lion distribution with the fishery; d) redesign observer program sampling through analysis of logbook and observer data to improve coverage for bycatch and high risk species; e) conduct experiments with high risk sharks to estimate survivability of post capture release; and f) expand trigger limits in the sector to include high risk species that will assist in alerting the sector when major changes in catch/effort occurs. An additional potential future project described included: a) produce a species identification book to assist identification of some species and hence improve data collection by industry; b) create gillnet Code of Conduct that specifies good handling practices for both sharks and stingarees, with an emphasis on improving the life status of released sharks; c) skipper/crew member awareness program, with emphasis on addressing the gaps in the logbook system; and d) investigating avenues for assessing differences in slinging ratios for reducing incidental catch of seals.
Broad categories of data collection needs
Assessment of bycatch and discards

[26] AFMA. (2009). Shark Gillnet Fishery Bycatch And Discarding Workplan. AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2010/06/shark_gillnet_bdwp.pdf (Accessed 15/10/2014)

Verification/improve data collection
Ecosystems

Specific data collection activities

✓	Logbook	✓	Dedicated research projects		Owner / vessel registry
✓	CDR	✓	Interaction/bycatch studies		Permits
	State fishery landings		Survey of fishing gears		Quota allocation
	Recreational catch estimates		Reference points		Quota trading
✓	Observer / port measure		EMS		Economics
	Age data		Compliance	✓	Logbook Interactions
	Industry collected length freq.		VMS		MSE
✓	Fishery Independent Surveys		ELogs		
✓	Biological / stock structure studies	✓	Education		

Outputs

- Progress on the actions will be reported at 6 and 12 months
- Action item reports
- Code of Conduct
- Species ID book

19.1.18. Memorandum of Understanding between the Australian Fisheries Management Authority and the Department of the Environment and Heritage for the Reporting of Fisheries Interactions with Protected Species under the Environment Protection and Biodiversity Conservancy Act 1999 [27]

Description

The EPBC Act 1999 requires that interactions between fishing vessels and threatened, endangered or protected species are reported to the secretary within seven days. In order to streamline that reporting, and reduce the administrative reporting burden on individual fishers, the Memorandum of Understanding (MOU) was implemented during 2005 whereby fishing concession holders report interactions to AFMA through their fishing logbooks, and AFMA compile and periodically report those interactions to DoE (previously DEH)

Objectives

While no specific objectives are listed in the MOU, it was established to streamline the reporting requirements for fishers interacting with species protected under the EPBC Act.

Measures by which the objectives are to be attained

a) Provide logbooks with the ability to report TEP interactions and that includes location, time and date, presence of observer, sex and life stage, and require that interactions are reported;

b) Provide quarterly reports to DoE aggregated by fishery, fishing method, species and including number of each species interacted with, life status, interaction type and method of fishing;

c) DoE may also seek additional information including detailed reports on individual interactions; and

d) Publish quarterly reports on DoE's website.

Broad categories of data collection needs

Assessment of bycatch and discards

Specific data collection activities

	Logbook		Dedicated research projects		Owner / vessel registry
	CDR		Interaction/bycatch studies		Permits
	State fishery landings		Survey of fishing gears		Quota allocation
	Recreational catch estimates		Reference points		Quota trading
	Observer / port measure		EMS		Economics
	Age data		Compliance	✓	Logbook Interactions
	Industry collected length freq.		VMS		MSE
	Fishery Independent Surveys		ELogs		
✓	Biological / stock structure studies	✓	Education		

Outputs

- Quarterly reports to DoE
- Reports published on DoE website

[27] Anon. (2005). Memorandum of Understanding Between the Australian Fisheries Management Authority and the Department of the Environment and Heritage for the Reporting of Fisheries Interactions with Protected Species Under the Environment Protection and Biodiversity Conservancy Act 1999. AFMA, Canberra. p://www.afma.gov.au/wp-content/uploads/2010/06/mou.pdf (Accessed 21/10/2014)

19.1.19. Orange Roughy Conservation Program[28] and the Orange Roughy Stock Rebuilding Strategy[29]

Description

In 2006, Orange Roughy was listed as conservation dependent under the EPBC Act 1999. In response, AFMA implemented the Conservation Program in the same year to ensure that Orange Roughy do not become vulnerable, endangered or critically endangered in the following 5 years. At the time, Orange Roughy were known to be overfished in the Eastern, Southern and Western management zones, not overfished in the Cascade Plateau Zone, and their stocks uncertain in other zones. The Conservation Program describes the aim and requirements, actions to be undertaken to achieve the aim, performance measures, timeframe for recovery, monitoring recovery and the review process. In 2015, the Orange Roughy Stock Rebuilding Strategy replaced the Conservation Program.

Objectives

Orange Roughy Conservation Program

To conserve Orange Roughy to ensure its long term survival in nature and recover the species to ecologically sustainable levels.

Orange Roughy Stock Rebuilding Strategy

The primary objective of this Strategy is to rebuild Orange Roughy stocks to levels where they can be harvested in an ecologically sustainable manner consistent with the Commonwealth Fisheries Harvest Strategy Policy 2007 (HSP) and ultimately maximise the economic returns to the Australian community.

Specific objectives of the Strategy are:

1. To rebuild Orange Roughy stocks (except Eastern Zone and Cascade Plateau that are assessed as having rebuilt) in the area of the SESSF to the limit reference biomass point (B_{LIM}) of 20 per cent of the unfished spawning biomass within a biologically reasonable time frame; being one mean generation time (56 years) plus 10 years (66 years) from the start of the ORCP. That is, to reach B_{LIM} by no later than 2072;
2. Having reached B_{LIM}, rebuild these stocks to the maximum sustainable yield biomass level of 40 per cent of the unfished spawning biomass (B_{MSY}) using the harvest control rules outlined in the SESSF Harvest Strategy Framework. These harvest control rules provide for a restricted TAC to allow limited fishing whilst rebuilding from B_{LIM} to B_{MSY}; and
3. Once B_{MSY} is reached, pursue the default maximum economic yield biomass level of 48 per cent of unfished spawning biomass (B_{MEY}).

Measures by which the objectives are to be attained

a) Catch limits – incidental or conservative TACs;

b) Spatial closures – implemented in deep water areas within the SESSF except where targeted Orange Roughy fishing is allowed or specific management arrangements are in place to target other deepwater species;

c) Effort restrictions – limited entry;

d) Reporting and monitoring – catch reporting, observer data, Acoustic Optical Surveys;

e) Assessment – Conducting stock assessments under the SESSF Harvest Strategy Framework.

Broad categories of data collection needs

Assessments of target species

Licencing / quota

Specific data collection activities

[28] AFMA (2006). Orange Roughy Conservation Program. AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2010/07/n20061207.pdf (Accessed 15/10/2014)

[29] AFMA (2006). Orange Roughy Stock Rebuilding Strategy. AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2014/12/SESSF-Orange-roughy-rebuilding-strategy-2015-FINAL.pdf (Accessed 31/8/2016)

√	Logbook		Dedicated research projects	√	Owner / vessel registry
√	CDR		Interaction/bycatch studies	√	Permits
	State fishery landings		Survey of fishing gears	√	Quota allocation
	Recreational catch estimates	√	Reference points	√	Quota trading
√	Observer / port measure		EMS	√	Economics
√	Age data	√	Compliance		Logbook Interactions
	Industry collected length freq.	√	VMS		MSE
√	Fishery Independent Surveys	√	Elogs		
√	Biological / stock structure studies		Education		

Outputs

- Annual review of program
- independent review of the quantitative stock assessments for Orange Roughy.
- Formal review after 5 years

19.1.20. School Shark Stock Rebuilding Strategy 2008[30] and the School Shark (*Galeorhinus galeus*) Stock Rebuilding Strategy Revised 2015[31]

Description

School Shark has been assessed as overfished since annual assessments commenced in 1992. A 2001 assessment estimated that School Shark pup production was 9–14% of historical levels (Punt and Pribac, 2001), and the most recent assessment showed the stock was still below the limit reference point (Thomson, 2012). In accordance with the Commonwealth Harvest Strategy Policy and pursuant of the objectives set out in the Fisheries Management Act 1991, the School Shark Stock Rebuilding Strategy was implemented in 2008 to rebuild stocks to the target biomass level. The development and implementation of this rebuilding strategy is also a condition of the SESSF Wildlife Trade Operation (WTO) accreditation under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). The School Shark Stock Rebuilding Strategy includes objectives, description of management arrangements to achieve the objectives, performance measures, a description of data to be collected and analysed and a schedule of review.

Objectives

2008 Stock Rebuilding Strategy

Following the formulation of the Commonwealth Fisheries Harvest Strategy Policy, the objectives of this rebuilding strategy are:

1. To rebuild school shark stocks in the area of the Southern and Eastern Scalefish and Shark Fishery to the limit reference biomass level - B_{20} within a biologically reasonable timeframe.
2. Having reached B_{20} rebuild School Shark stocks in the area of the Southern and Eastern Scalefish and Shark Fishery to the target biomass level - B_{40} (the default B_{MSY} point contained in the Commonwealth Fisheries Harvest Strategy Policy) within a biologically reasonable timeframe (a 'typical' biologically reasonable time is 10 years plus one mean generation time and one mean generation time for School Shark = 20 to 25 years).

2015 Stock Rebuilding Strategy

The broad objective of this Strategy is to return the stock to ecologically sustainable levels and ultimately maximise the economic returns to the Australian community from the resource. In line with the HSP the specific objectives are:

1. to rebuild school shark in the area of the SESSF to the default limit reference biomass level (B_{LIM}) of 20 per cent of unfished levels within a biologically reasonable time frame; three times the mean generation time (66 years) from the date of the 2008 Strategy
2. having reached B_{LIM}, rebuild school s hark in the area of the SESSF to the default maximum sustainable yield biomass level of 40 per cent of unfished levels (B_{MSY}); and
3. once B_{MSY} is reached, use appropriate modelling to determine the target reference point (B_{TARG}) biomass for school s hark and a trajectory for the rebuilding of the stock to that point - OR rebuild to the default maximum economic yield level (B_{MEY}) of 48 per cent of unfished stocks

Measures by which the objectives are to be attained

The School Shark Stock Rebuilding Strategy includes detailed descriptions of management arrangement to be implemented to achieve the objectives and a section on data collection and analysis. Key points of the data collection and analysis section are described below (note that some of those described are a part of staged management options and are not necessarily in place).

a) Area closures – a variety of spatial and temporal closures are in place. Fishing activities in relation to these closures is monitored using VMS;

b) gear restrictions and selectivity – the gillnet sector has restrictions in minimum and maximum mesh

[30] AFMA (2008). School Shark Stock Rebuilding Strategy 2008. AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2010/07/school_shark_rebuild.pdf (Accessed 15/10/2014)

[31] AFMA (2015). School Shark (Galeorhinus galeus) Stock Rebuilding Strategy Revised 2015. AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2014/12/School-Shark-Rebuilding-Strategy.pdf (Accessed 19/08/2016)

size, and the automatic longline vessels have a hook limit.

c) catch limits – Bycatch TACs are set and monitored through logbooks and the quota system, and is based on the estimated unavoidable catch when targeting Gummy Shark. Automatic longline vessels have a 100 kg trip limit;

d) compliance – VMS, observer program and tightening of reporting standards;

e) minimum length and processing standards – monitored by compliance;

f) processing standards for landing sharks – all sharks landed in the SESSF are subject to specific processing standards to ensure that species identification and lengths can be verified when landed. Shark finning is not permitted in the SESSF.

g) limited entry;

h) structural adjustment;

i) close monitoring of discards and total fishing mortality – If total mortality is likely to exceed levels that support rebuilding, AFMA will implement additional management measures to keep fishing mortality at levels that support rebuilding.

Broad categories of data collection needs

Assessments of target species
Assessment of bycatch and discards
Licencing / quota
Verification/improve data collection

Specific data collection activities

√	Logbook	√	Dedicated research projects		Owner / vessel registry
√	CDR		Interaction/bycatch studies		Permits
√	State fishery landings		Survey of fishing gears		Quota allocation
	Recreational catch estimates	√	Reference points		Quota trading
√	Observer / port measure	√	EMS		Economics
√	Age data	√	Compliance		Logbook Interactions
	Industry collected length freq.	√	VMS		MSE
√	Fishery Independent Surveys	√	ELogs		
√	Biological / stock structure studies		Education		

Outputs

- Status of school shark stocks will be reviewed when the results of the fishery independent measure of abundance using close kin genetics techniques are available and in any case after five years.
- AFMA will report annually on stock status and performance against the goals of the rebuilding strategies to DoE. SharkRAG will assess performance of the stock against the goals of the rebuilding strategy as part of the review of stock assessments.
- AFMA will report on observer coverage and compliance with the rebuilding strategy to DEWHA

19.1.21. Eastern Gemfish Stock Rebuilding Strategy 2008[32] and draft Eastern Gemfish (*Rexea solandri*) Stock Rebuilding Strategy Revised 2014[33]

Description

Eastern Gemfish has been assessed as overfished since 1992. A 1999 assessment estimated the spawning biomass at 5–26% of the 1979 spawning biomass, and the most recent assessment has estimates spawning biomass at 15% of the 1968 level (Little and Rowling, 2011). In accordance with the Commonwealth Harvest Strategy Policy and pursuant the objectives set out in the Fisheries Management Act 1991, the Eastern Gemfish Stock Rebuilding Strategy was implemented in 2008 to rebuild stocks to the target biomass level. The development and implementation of this rebuilding strategy is also a condition of the SESSF Wildlife Trade Operation (WTO) accreditation under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). The Eastern Gemfish Stock Rebuilding Strategy includes objectives, a description of management arrangements to achieve the objectives, monitoring recovery and performance measures and a schedule of review. The 2008
Eastern Gemfish Stock Rebuilding Strategy was revised during 2014, and the draft is currently in consultation phase. This revised draft is more comprehensive than the 2008 document, and includes sections on management actions to achieve the objectives, monitoring and evaluation and stock assessments and data collection.

Objectives

2008 Stock Rebuilding Strategy

1. To rebuild Eastern Gemfish stocks in the area of the Southern and Eastern Scalefish and Shark Fishery to the limit reference biomass level - B_{20} within a biologically reasonable time frame, being approximately 9 years.
2. Having reached B_{20} rebuild eastern gemfish stocks in the area of the Southern and Eastern Scalefish and Shark Fishery to the target biomass level - B_{40} (the default B_{MSY} point contained in the Commonwealth Fisheries Harvest Strategy Policy) within a biologically reasonable time frame, for example 10 years plus one mean generation time or three times the mean generation time, wherever is the shorter, being approximately 19 to 27 years.
3. Once the target biomass level is reached to use appropriate modelling to determine the target or B_{MEY} biomass for Eastern Gemfish and determine a trajectory for the rebuilding of the stock to that point.

2014 Stock Rebuilding Strategy

Consistent with the Fisheries Management Act 1991 (the Act) the broad objective of the Strategy is to return Eastern Gemfish stocks to ecologically sustainable levels and ultimately maximise the economic returns to the Australian community from the resource. In line with the HSP there are three rebuilding objectives:

1. To rebuild Eastern Gemfish in the area of the SESSF to the default limit reference level of 20% of unfished spawning stock biomass (B_{LIM}) within a biologically reasonable time frame, being approximately 19 years (one mean generation time plus 10 years).
2. Having reached B_{LIM}, rebuild Eastern Gemfish to the maximum sustainable yield level of 40% of unfished spawning stock biomass (B_{MSY}).
3. Once B_{MSY} is reached, pursue the biomass level which aims to maximise net economic returns, currently 48% of unfished spawning stock biomass (B_{MEY}).

Measures by which the objectives are to be attained

The Eastern Gemfish Stock Rebuilding Strategy 2008 includes detailed descriptions of management arrangement to be implemented to achieve the objectives including current (then) management arrangements, issues with those arrangements and future management arrangements. There is also a

[32] AFMA (2008). Eastern Gemfish Stock Rebuilding Strategy 2008. AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2010/07/eastern_gemfish_rebuild.pdf (Accessed 15/10/2014)

[33] AFMA (2014). Draft Eastern Gemfish (*Rexea solandri*) Stock Rebuilding Strategy Revised 2014, AFMA, Canberra. http://www.afma.gov.au/wp-content/uploads/2014/10/draft-eastern-gemfish-rebuilding-strategy-26.9.14.pdf (Accessed 16/10/2014)

section on monitoring recovery and performance measures, and the observer monitoring program. Aspects of the staged rebuilding plan and data requirements for the 2008 document are described below

a) Use of "move-on" provisions – voluntary measure where by industry members communicate catches of small Eastern Gemfish so they can avoid incidental catches and fishing mortality. While this is voluntary, observers will provide information on industry application of this provision;
b) Investigate additional measure of reducing discards of juvenile fish – undertake research with particular focus on gear modifications, spatial closures, and review bycatch quotas;
c) Adoption of more selective gear;
d) Industry and AFMA communicated closure of spawning aggregations;
e) Increased observer program during winter months to improve precision of discard information recorded in logbooks;
f) Undertake spawning survey;
g) Update stock assessment;
h) Mandatory fishing gear requirements through increased codend mesh size;
i) Lowering TAC;
j) Mandatory fishing closure to reduce incidental capture of pre-spawning and spawning fish.

Aspects of the staged rebuilding plan and data requirements for the 2014 document are described below

a) Incidental catch TAC – provide for a zero targeting TAC, review incidental catch TAC annually;
b) Trawl gear selectivity – Minimum mesh size was increased to 90 mm during 2006, and a recent survey showed that almost half of operators are using mesh size greater than 100 mm;
c) Limited entry;
d) Existing fishery closures (e.g. enforce Upper Slope Dogfish closure);
e) Use observer data to estimate discard rate, with particular focus on coverage during times and in areas of high abundance to obtain better length and otolith samples and better estimates of discard rates;
f) Regular fishery independent survey to obtain index of abundance;
g) 50kg Eastern Gemfish trip limits for NSW fishers;
h) Education through online learning modules being developed by AFMA and SETFIA that include information on arrangements for Eastern Gemfish;
i) Monitor location and time of Eastern Gemfish catches for consideration of implementing spatial and temporal closures if appropriate;
j) Investigating use of EMS to supplement observer program and potentially estimate size and species composition of catch.

Broad categories of data collection needs

Assessments of target species
Assessment of bycatch and discards
Licencing / quota
Verification/improve data collection
Ecosystem

Specific data collection activities

✓	Logbook	✓	Dedicated research projects	✓	Owner / vessel registry
✓	CDR	✓	Interaction/bycatch studies	✓	Permits
✓	State fishery landings	✓	Survey of fishing gears	✓	Quota allocation
	Recreational catch estimates	✓	Reference points		Quota trading
✓	Observer / port measure	✓	EMS		Economics

✓	Age data	✓	Compliance		Logbook Interactions
	Industry collected length freq.	✓	VMS		MSE
✓	Fishery Independent Surveys	✓	ELogs		
	Biological / stock structure studies	✓	Education		

Outputs

- Investigate and report to the Department of the Environment, Water, Heritage and the Arts (DEWHA) by 30 June 2008 on methods of reducing the capture and subsequent discard of juvenile Eastern Gemfish
- ShelfRAG will assess performance of the stock against the goals of the rebuilding strategy as part of the review of stock assessments
- AFMA will report annually on stock status and performance against the goals of the rebuilding strategy to DEWHA.
- AFMA will also report on observer coverage and compliance with the rebuilding strategy to DEWHA

19.1.22. Australian Sea Lion Management Strategy [34]

Description

In response to concerns over the potential risk to Australian Sea Lion populations of interactions with gillnets used by the SGSHS, AFMA developed the Australian Sea Lion Management Strategy to reduce and monitor interactions. The strategy includes increasing the level of monitoring by observers, development of an industry Code of Conduct, research, an ongoing review of new data to inform management decisions and implementation of fisheries closures.

Objectives

This strategy is designed to meet AFMA's obligations under the Fisheries Management Act 1991 and the EPBC Act. The broad objectives are to ensure that the exploitation of fisheries resources is sustainable with regard to target and non-target species as well as the broader marine environment, and to maximise the net economic returns to the Australian community from the management of Australian fisheries.

Within this broader context the specific objectives of the strategy are to significantly reduce the ecological risk the SESSF poses to Australian Sea Lions and enable their recovery.

Measures by which the objectives are to be attained

Measures to achieve the objectives are:

a) implement long-term management measures, including formal fisheries closures and other actions, that will lead to a significant reduction of the impact of fishing activity on Australian sea lions. These measures will be clearly directed towards enabling recovery of the species, including all sub–populations; and

b) in consultation with marine mammal experts, continue to monitor and review the adequacy of management measures towards the objective of avoiding mortality of, or injuries to, Australian Sea Lions so as to enable the recovery of Australian sea lion populations, including all sub-populations.

Broad categories of data collection needs

Assessment of bycatch and discards
Ecosystem
Verification/improve data collection

Specific data collection activities

	Logbook	✓	Dedicated research projects		Owner / vessel registry
	CDR	✓	Interaction/bycatch studies		Permits
	State fishery landings	✓	Survey of fishing gears		Quota allocation
	Recreational catch estimates		Reference points		Quota trading
✓	Observer / port measure	✓	EMS		Economics
	Age data	✓	Compliance	✓	Logbook Interactions
	Industry collected length freq.	✓	VMS		MSE
	Fishery Independent Surveys		ELogs		
✓	Biological / stock structure studies	✓	Education		

[34] AFMA. (2010). Australian Sea Lion Management Strategy, Australian Fisheries Management Authority, Canberra. http://www.afma.gov.au/wp-content/uploads/2010/07/sea_lion_management_strategy_2010.pdf (Accessed 17/11/2014)

Outputs
• Quarterly reviews of the effectiveness of the strategy during the first year • Annual review of strategy after first year • Annual reports on the implementation of the strategy • Code of Conduct • Research reports • Spatial closures • Adaptive management system of spatial closures • Increased observer coverage

19.1.23. Dolphin Strategy: Minimising Gillnet Bycatch [35]

Description

A sharp increase in the reported bycatch of dolphins in South Australia by bottom-set gillnet fishers during 2011 necessitated development of the Dolphin Strategy. It aims to reduce the risk of dolphin bycatch by putting responsibility on the fishers. This promotes incentive for individuals to develop their own mitigation strategies, without unduly impacting on fishing operations through management arrangements such as "one out, all out" closures. The Dolphin Strategy describes objectives, actions to be taken to achieve the objectives, information needs and research and review and performance measures of the strategy.

Objectives

This Strategy aims to minimise the bycatch of dolphins in gillnets in the SESSF to as close to zero as possible. To achieve this, the short-term objective of this Strategy is for each gillnetting boat to adopt the measures best suited to their individual operation to minimise their risk of bycatch.

Measures by which the objectives are to be attained

The objectives are to be achieved by:

1. improving information on the nature of interactions between dolphins and fishing gear, particularly what species are involved (interaction evaluation reports, e-monitoring, define information needs and research priorities);
2. providing incentives for individual operators to reduce dolphin bycatch and implement and develop mitigation measures best suited to their circumstances and location (set management response for any dolphin interaction, staged implementation of individual responsibility to minimise bycatch with escalating closures); and
3. identifying options and best practice measures to support fishers in minimising dolphin bycatch.

Broad categories of data collection needs

Assessment of bycatch and discards
Ecosystem
Verification/improve data collection

Specific data collection activities

	Logbook	✓	Dedicated research projects		Owner / vessel registry
	CDR	✓	Interaction/bycatch studies		Permits
	State fishery landings	✓	Survey of fishing gears		Quota allocation
	Recreational catch estimates		Reference points		Quota trading
✓	Observer / port measure	✓	EMS		Economics
	Age data	✓	Compliance	✓	Logbook Interactions
	Industry collected length freq.	✓	VMS		MSE
	Fishery Independent Surveys		ELogs		
	Biological / stock structure studies	✓	Education		

Outputs

- Phone / email report to AFMA of any dolphin mortality no later than 48 hours after capture (fisher)

[35] AFMA (2014). Dolphin Strategy: Minimising Gillnet Bycatch, Australian Fisheries Management Authority, Canberra. http://www.afma.gov.au/wp-content/uploads/2014/02/AFMA-Dolphin-Strategy-September-2014.pdf (Accessed 12/03/2015)

- Dolphin Bycatch Evaluation Report for any dolphin bycatch (fishers and AFMA)
- Management responses as required (AFMA)
- Review of the Dolphin Strategy after 12 months

19.1.24. Upper-Slope Dogfish Management Strategy [36]

Description

Populations of four species of upper-slope dogfish have undergone significant declines in south-eastern Australia, and consequently, two of those species — Harrisson's Dogfish and Southern Dogfish — have been listed as conservation dependent. The Upper-Slope Dogfish Management Strategy was developed to ensure that the management requirements are in place to satisfy those Conservation Dependent listings under the EPBC Act. The Strategy outlines an objective, management actions required to maintain and recover stocks and a monitoring and implementation plan.

Objectives

The objective of the Strategy is to promote the recovery of Harrisson's Dogfish and Southern Dogfish.

Measures by which the objectives are to be attained

1. Catch limits to prevent targeting
2. Area closures
3. Annual catch trigger limits
4. establishment of limit and target reference points using a habitat proxy; estimation of depletion by species, stock and fishery sub-regions; establishment of rebuilding timeframes;
5. identification of candidate areas for closures;
6. identification of Area and Network closure options using a management strategy evaluation (MSE) approach; and
7. determination of the extent of overlap of existing fishery closures and marine reserves with the distribution of Harrisson's Dogfish and Southern Dogfish
8. increased monitoring

Broad categories of data collection needs

Assessment of bycatch and discards
Ecosystem
Verification/improve data collection

Specific data collection activities

✓	Logbook	✓	Dedicated research projects		Owner / vessel registry
	CDR	✓	Interaction/bycatch studies		Permits
✓	State fishery landings	✓	Survey of fishing gears		Quota allocation
	Recreational catch estimates	✓	Reference points		Quota trading
✓	Observer / port measure	✓	EMS		Economics
	Age data	✓	Compliance		Logbook Interactions
	Industry collected length freq.	✓	VMS		MSE
✓	Fishery Independent Surveys	✓	ELogs		
✓	Biological / stock structure studies	✓	Education		

Outputs

[36] AFMA (2012). Upper-Slope Dogfish Management Strategy, Australian Fisheries Management Authority, Canberra. http://www.afma.gov.au/wp-content/uploads/2012/12/Upper-slope-Dogfish-Management-Strategy-14December-2012-FINAL.pdf?9370a8 (Accessed 12/03/2015)

- research and monitoring plan for this Strategy within 12 months of the Strategy's implementation (AFMA)
- Catch limits
- Area closures
- annual review of the available data and performance against the goals of the management strategy to DSEWPaC (AFMA)

Figure 61. Broad categories of data collection needs for the SESSF, and data collection programs used to obtain data

Assessments of target species	Assessment of bycatch and discards	Ecosystem	Verification/improve data collection	Licencing / quota	Socio-economics
Modelling Harvest Strategy MSE	ERA Harvest Strategy Mitigation	ERA Ecosystem modelling Climate change			
Logbook / CDR State fishery logbooks Recreational surveys Observer / port measurer Fishery Independent Surveys Age data Biological / stock structure studies Reference points MSE Industry collected length frequencies	Logbook / CDR Logbook interactions Observer Fishery Independent Surveys Biological studies Dedicated research projects Interaction and bycatch mitigation studies Survey of fishing gears	Logbook / CDR Logbook interactions Observer Fishery Independent Surveys Dedicated research projects	EMS Observer Compliance VMS ELogs Education	Owner / vessel registry Permits Quota allocation Quota trading	MSE Economics

20. Appendix 6: Proposed classification and assessment of SESSF species

CAAB Code	Common Name	2012-2014 avg catch	% GVP	Category	Ref point	FIS Category	Default	Current	Proposed
37296001	Tiger Flathead	2,611,218	21.1%	Primary	MEY	Target	Tier 1	Tier 1	Tier 1
37017001	Gummy Shark	1,483,392	14.3%	Primary	MEY	Target	Tier 1	Tier 1	Tier 1
37227001	Blue Grenadier	3,020,910	11.0%	Primary	MEY	Target	Tier 1	Tier 1	Tier 1
37228002	Pink Ling	965,901	8.1%	Primary	MEY	Target	Tier 1	Tier 1	Tier 1
37296002	Deepwater Flathead	967,077	7.5%	Primary	MEY	Secondary	Tier 1	Tier 1	Tier 1
37445001	Blue-Eye Trevalla	300,516	3.8%	Primary	MEY	Byproduct	Tier 1	Tier 4	Tier 4
37255009	Orange Roughy	486,932	3.3%	Primary	MEY	Byproduct	Tier 1	Tier 1	Tier 1
37330014	Eastern School Whiting	560,822	2.5%	Primary	MEY	Byproduct	Tier 1	Tier 1	Tier 4
23636004	Gould's Squid	672,613	2.0%	Primary	MEY	Byproduct	Tier 1	ERA	Tier 5
37258004	Bight Redfish	244,210	1.7%	Primary	MEY	Byproduct	Tier 1	Tier 1	Tier 4
37445006	Silver Warehou	623,749	1.7%	Primary	MEY	Target	Tier 1	Tier 1	Tier 4
37465006	Ocean Jacket	450,879	1.2%	Secondary	MSY	Byproduct	Tier 4	ERA	Tier 5
37264003	Mirror Dory	312,400	1.2%	Secondary	MSY	Target	Tier 4	Tier 4	Tier 5
37377003	Jackass Morwong	310,662	1.5%	Secondary	MSY	Target	Tier 4	Tier 1	Tier 5
37288006	Latchet	230,170	0.5%	Secondary	MSY	Byproduct	Tier 4	ERA	ERA
37440002	Frostfish	224,023	1.2%	Secondary	MSY	Secondary	Tier 4	ERA	ERA
37287001	Reef Ocean Perch	210,225	1.0%	Secondary	MSY	Byproduct	Tier 4	Tier 4	Tier 5
28714005	Royal Red Prawn	190,547	0.7%	Secondary	MSY	Byproduct	Tier 4	Tier 4	Tier 5
37023000	Sawsharks	189,145	0.6%	Secondary	MSY	Byproduct	Tier 4	Tier 4	Tier 5
37017008	School Shark	173,662	1.4%	Secondary	MSY	Secondary	Tier 4	Tier 1	Tier 1
37439002	Gemfish	158,257	0.6%	Secondary	MSY	Target	Tier 4	Tier 1	Tier 1
37288001	Red Gurnard	156,118	0.7%	Secondary	MSY	Secondary	Tier 4	ERA	ERA
37224002	Ribaldo	134,003	0.4%	Secondary	MSY	Byproduct	Tier 4	Tier 4	Tier 5
37337062	Silver Trevally	130,327	0.8%	Secondary	MSY	Byproduct	Tier 4	Tier 4	Tier 5
37264001	King Dory	121,824	1.1%	Secondary	MSY	Target	Tier 4	ERA	ERA
37465000	Leatherjackets	112,200	0.3%	Secondary	MSY	Byproduct	Tier 4	ERA	ERA
37024001	Australian Angelshark	108,056	0.3%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37266001	Spikey Oreodory	91,339	0.4%	Byproduct	>LIM	Byproduct	Tier 5	Tier 4	Tier 5
37400000	Stargazers	90,905	0.6%	Secondary	MSY	Byproduct	Tier 4	ERA	ERA
37258003	Redfish	78,055	0.4%	Secondary	MSY	Target	Tier 5	Tier 1	Tier 5
37024002	Ornate Angelshark	77,892	0.2%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37264004	John Dory	74,675	0.8%	Secondary	MSY	Target	Tier 4	Tier 3	Tier 4
37367001	Yellowspotted Boarfish	73,745	0.4%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37043001	Elephantfish	69,653	0.1%	Byproduct	>LIM	Byproduct	Tier 5	Tier 4	Tier 4
23607901	Cuttlefish (Mixed)	59,282	0.3%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37005002	Broadnose Shark	54,602	0.2%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37020905	Platypus Sharks (Mixed)	52,154	0.2%	Byproduct	>LIM	Byproduct	Tier 5	Tier 4	Tier 5
37353001	Snapper	46,134	0.5%	Secondary	MSY	Byproduct	Tier 4	ERA	ERA
23659000	Octopuses	44,654	0.4%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37369002	Knifejaw	43,940	0.2%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37445005	Blue Warehou	43,857	0.2%	Secondary	MSY	Secondary	Tier 5	Tier 4	Tier 4
23617000	Calamari	34,635	0.6%	Secondary	MSY	Byproduct	Tier 4	ERA	ERA
37031000	Skates	31,455	0.1%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37377002	Grey Morwong	31,156	0.2%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37355001	Bluestriped Goatfish	26,590	0.3%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37337002	Common Jack Mackerel	26,147	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37377004	Blue Morwong	24,989	0.1%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37311006	Hapuku	24,829	0.3%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37039001	Southern Eagle Ray	24,392	0.1%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37367000	Boarfishes	24,277	0.1%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37228001	Tusk	23,332	0.5%	Secondary	MSY	Byproduct	Tier 4	ERA	ERA

37020906	Deepwater Dogfishes Unspecified	22,743	0.1%	Secondary	MSY	Byproduct	Tier 5	Tier 4	Tier 5
37020006	Spikey Dogfish	22,093	0.1%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37018001	Bronze Whaler	21,640	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37266902	Oreodories (Mixed)	19,535	0.1%	Byproduct	>LIM	Byproduct	Tier 5	Tier 4	Tier 5
37266002	Oxeye Oreodory	19,196	0.1%	Byproduct	>LIM	Byproduct	Tier 5	Tier 4	Tier 5
37026000	Guitarfishes Unspecified	19,034	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37264002	Silver Dory	18,499	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37990018	Skates and Rays	18,356	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37015001	Draughtboard Shark	17,630	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37367005	Blackspot Boarfish	16,232	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37020004	Longsnout Dogfish	14,939	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37013000	Wobbegongs Blind Nurse Shark	14,569	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37439001	Barracouta	14,120	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37042000	Ghostsharks	13,733	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
24207000	Bailer Shells	13,722	0.2%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37015013	Whitefin Swellhark	13,342	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37017003	Whiskery Shark	11,060	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37020000	Dogfishes	11,060	0.0%	Byproduct	>LIM	Target	Tier 5	ERA	ERA
37441911	Mackerel (Mixed)	10,946	0.1%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37337006	Yellowtail Kingfish	8,814	0.1%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37020904	Roughskin Dogfishes (Mixed)	8,661	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37027999	Fiddler Rays Unspecified	8,079	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37441001	Blue Mackerel	7,971	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37010001	Shortfin Mako	7,821	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37258002	Alfonsino	7,640	0.1%	Byproduct	>LIM	Byproduct	Tier 5	Tier 3	Tier 5
37445004	Rudderfish	7,488	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37067000	Conger Eels	7,221	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37990003	Sharks (Mixed)	6,108	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37311902	Hapuku and Bass Groper	5,381	0.1%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37345901	Redbait (Mixed)	5,145	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37378001	Striped Trumpeter	4,954	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37269001	Common Veilfin	4,910	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37287005	Common Gurnard Perch	4,868	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37445011	White Warehou	4,647	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
28850000	Crabs	4,610	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37345900	Rubyfish (Mixed)	4,472	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
28821000	Bugs - Shovel & Slipper Lobsters	4,286	0.2%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37465003	Mosaic Leatherjacket	3,910	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37018003	Dusky Whaler	3,678	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37229003	Messmate Fish	3,359	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37224900	A Morid Cod	3,213	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37122000	Lanternfishes	3,068	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37296006	Rock Flathead	2,948	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37019004	Smooth Hammerhead	2,741	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37020007	Greeneye Dogfish	2,600	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37024000	Angel Sharks	2,559	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37287103	Ocean Perch (T Carnomagula)	2,017	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37342001	Ray's Bream	1,983	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37258001	Imperador	1,849	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
28915002	Giant Crab	1,577	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37020042	Velvet Dogfish	1,530	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37232000	Whiptails and Rat-Tails	1,528	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37120001	Blacktip Cucumberfish	1,508	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37367003	Longsnout Boarfish	1,443	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37990015	Sole (Mixed)	1,253	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37344900	Australian Salmon	1,122	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
28730000	Carid Prawns	1,066	0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA

37020001	Endeavour Dogfish	1,028		0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37990009	Flounders (Mixed All Types)	1,025		0.0%	Byproduct	>LIM	Byproduct	Tier 5	ERA	ERA
37467000	Toadfishes Unspecified	947		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37384043	Eastern Blue Groper	936		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37440004	Largehead Hairtail	888		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311000	Temperate Basses & Rockcods	885		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37350001	Lined Javelinfish	883		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37367004	Bigspine Boarfish	856		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28821001	Deepwater Bug	850		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37254001	Black Spinyfin	808		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
23615000	Squids	801		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37287006	Thetis Fish	745		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37264010	Rosy Dory	728		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37439003	Oilfish	724		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37355000	Goatfishes	723		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37378002	Bastard Trumpeter	716		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37266003	Smooth Oreodory	661		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311001	Eastern Orange Perch	652		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37224006	Red Cod	542		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37287093	Bigeye Ocean Perch	522		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337007	Samsonfish	483		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37018004	Blue Shark	479		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37442001	Swordfish	478		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37117001	Sergeant Baker	439		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37015000	Catsharks	438		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37018901	Blacktip Shark (Mixed)	404		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37085790	Herring	376		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37327000	Cardinalfishes	352		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37258006	Yelloweye Redfish	333		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311055	Splendid Perch	315		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37354001	Mulloway	303		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37258005	Swallowtail	296		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37445014	Ocean Blue-Eye Trevalla	278		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37010004	Porbeagle	261		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37330001	King George Whiting	255		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337000	Trevallies and Scads	247		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37334002	Tailor	245		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311910	Bar Rockcod	230		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337003	Yellowtail Scad	218		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37228008	Rock Ling	217		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37228901	Ling (Mixed)	190		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37018000	Whaler and Weasel Sharks	176		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37353013	Tarwhine	162		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28836000	King Crabs	160		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37377001	Magpie Perch	150		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37035000	Stingrays	133		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28821004	Eastern Balmain Bug	127		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337029	Rainbow Runner	120		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37296037	Southern Bluespotted Flathead	120		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37005005	Bluntnose Sixgill Shark	119		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37367009	Pelagic Armourhead	118		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37255004	Darwin's Roughy	113		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37378900	Trumpeters	98		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37296036	Longspine Flathead	96		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37264000	Dories & Lookdown Dories	92		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37441005	Albacore	89		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37224017	Schmidt's Cod	85		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37297000	Ghost Flatheads	68		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37441912	Tuna (Mixed)	66		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA

37296003	Southern Sand Flathead	65		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37224903	Moridae	65		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020008	Whitespotted Dogfish	61		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37441003	Skipjack Tuna	58		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37296004	Dusky Flathead	57		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020014	Smalltooth Cookiecutter Shark	56		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37367002	Giant Boarfish	55		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37361003	Moonlighter	44		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232031	Kaiyomaru Whiptail	37		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37008003	Sandtiger Shark	34		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37063003	Common Pike Eel	32		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311901	Rockcod	29		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37268900	Moonfish (Mixed)	29		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37361009	Silver Sweep	28		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37085002	Australian Sardine	27		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37384001	Western Pigfish	24		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37255000	Roughies	24		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37377009	Red Morwong	24		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37470002	Ocean Sunfish	24		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37018021	Bull Shark	23		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37192001	Estuary Cobbler	21		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311095	Longfin Perch	21		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37210000	Frogfishes	20		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37441002	Yellowfin Tuna	20		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346905	Sea Perch	19		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37288012	Blackfin Armour Gurnard	19		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37439008	Escolar	19		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020003	Brier Shark	18		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020023	Gulper Shark	18		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37305001	Smooth-Head Blobfish	18		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37287008	Southern Red Scorpionfish	16		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37007001	Port Jackson Shark	14		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37017006	Pencil Shark	13		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37441020	Australian Bonito	13		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37331000	Tilefishes	12		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37019001	Scalloped Hammerhead	11		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37441019	Butterfly Mackerel	11		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37227002	Southern Hake	11		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37349000	Silverbiddies	11		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37361007	Luderick	10		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232003	Gargoyle Fish	10		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37345001	Redbait	9		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37266005	Black Oreodory	9		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28712008	Giant Scarlet Prawn	9		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37377006	Banded Morwong	8		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37350903	Sea Bream	8		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37330000	Whitings	7		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37386000	Parrotfishes Unspecified	7		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37429038	Sleepy Cod	7		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
23270007	Commercial Scallop	7		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37377005	Dusky Morwong	7		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37351902	Emperor	4		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311005	Harlequin Fish	4		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37271001	Southern Ribbonfish	4		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37384003	Bluethroat Wrasse	4		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37350902	Grunter Bream (Mixed)	3		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346001	Rusty Jobfish	2		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37441011	Bigeye Tuna	2		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346033	Hussar	2		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37013010	Tawny Shark	1		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA

37346043	Blacktail Snapper	1		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37028002	Tasmanian Numbfish	1		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346032	Rosy Snapper	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37018027	Silvertip Shark	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346038	Flame Snapper	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37114013	Antipodean Slickhead	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37009002	Goblin Shark	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37018030	Grey Reef Shark	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37288901	Butterfly Gurnard (Mixed)	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37018022	Tiger Shark	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337901	Decapterus Spp.	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37255001	Blacktip Sawbelly	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37019000	Hammerhead Sharks	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37353003	Black Bream	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37338001	Mahi Mahi	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37441024	Wahoo	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337025	Amberjack	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37253000	Beardfishes	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37385009	Blue Weed Whiting	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346004	Red Emperor	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37279000	Bellowsfishes	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346007	Saddletail Snapper	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37278001	Smooth Flutemouth	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37353000	Bream (Mixed)	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311002	Butterfly Perch	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232004	Toothed Whiptail	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37288007	Cocky Gurnard	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37469002	Australian Burrfish	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020002	Black Shark	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37038008	Wide Stingaree	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337060	Rough-Ear Scad	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37031003	Whitespotted Skate	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37264005	New Zealand Dory	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232001	Southern Whiptail	0		0.0%	Bycatch	>LIM	Target	ERA	ERA	ERA
37297001	Deepsea Flathead	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37031010	Bight Skate	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37028003	Short-Tail Torpedo Ray	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37279001	Banded Bellowsfish	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37023002	Common Sawshark	0		0.0%	Bycatch	>LIM	Target	ERA	ERA	ERA
37038002	Banded Stingaree	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37038006	Common Stingaree	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37224009	Slender Cod	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37427001	Common Stinkfish	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37027001	Western Shovelnose Ray	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37279003	Crested Bellowsfish	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37023001	Southern Sawshark	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311053	Threespine Cardinalfish	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37031028	Grey Skate	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37031006	Melbourne Skate	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37035001	Smooth Stingray	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37031005	Longnose Skate	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020012	Golden Dogfish	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37035002	Black Stingray	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37067012	Swollenhead Conger	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37005001	Sharpnose Sevengill Shark	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37465007	Rough Leatherjacket	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37015009	Sawtail Catshark	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37266004	Warty Oreodory	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37038001	Sandyback Stingaree	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37345003	Cosmopolitan Rubyfish	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37031007	Thornback Skate	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA

37038007	Greenback Stingaree	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37296035	Toothy Flathead	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37288008	Roundsnout Gurnard	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37224004	Chiseltooth Grenadier Cod	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37279002	Common Bellowsfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37467002	Ringed Toadfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37288003	Butterfly Gurnard	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37441004	Southern Bluefin Tuna	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020010	Harrisson's Dogfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37031002	Sydney Skate	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020907	Lantern Sharks	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37384002	Western Blue Groper	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232002	Banded Whiptail	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37466010	Whitebarred Boxfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37400018	Speckled Stargazer	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37013005	Rusty Carpetshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37044001	Bigspine Spookfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37027006	Eastern Fiddler Ray	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37070001	Basketwork Eel	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
10000000	Sponges	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37296000	Flatheads	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37327001	Bigeye Deepsea Cardinalfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232007	Smooth Whiptail	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020011	Southern Dogfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37012001	Thresher Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37349001	Silverbelly	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37465032	Fourspine Leatherjacket	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232017	Blueband Whiptail	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37010003	White Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37288004	Robust Amour Gurnard	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37287003	Bighead Gurnard Perch	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37400004	Deepwater Stargazer	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37466002	Eastern Smooth Boxfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37042001	Ogilby's Ghostshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28820000	Spiny Lobsters	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311170	Bass Groper	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37255003	Sandpaper Fish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232014	Notable Whiptail	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37344002	Eastern Australian Salmon	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37390001	Barred Grubfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37224003	Bearded Rock Cod	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37288005	Painted Latchet	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37400005	Scaled Stargazer	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37465005	Velvet Leatherjacket	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37031018	Blue Skate	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37015027	Grey Spotted Catshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020005	Blackbelly Lanternshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37326001	Spotted Bigeye	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37345002	Bigscale Rubyfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28712001	Red Prawn	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282029	Spiny Pipehorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37224001	Eucla Cod	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37344004	Western Australian Salmon	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020019	Owston's Dogfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020013	Plunket's Dogfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37028001	Coffin Ray	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37067013	Deepsea Conger	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37461001	Longsnout Flounder	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37031009	Peacock Skate	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28710000	Prawns	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37466003	Shaw's Cowfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA

37021001	Prickly Dogfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37083001	Southern Spineback	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28820001	Southern Rock Lobster	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37469001	Globefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37056001	Southern Shortfin Eel	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28820002	Eastern Rock Lobster	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37015003	Gulf Catshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37327010	White Deepsea Cardinalfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37278002	Rough Flutemouth	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37400001	Bulldog Stargazer	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28911005	Blue Blue Swimmer Crab	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37400003	Common Stargazer	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37259001	Australian Pineapplefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37361004	Sea Sweep	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37022001	Bramble Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37465034	Gunn's Leatherjacket	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282009	Javelin Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37111001	Sloane's Viperfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
23617005	Southern Calamari	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37018038	Whitetip Reef Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020009	Leafscale Gulper Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37326002	Longfin Bigeye	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37027009	Eastern Shovelnose Ray	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37042003	Blackfin Ghostshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37445000	Trevallas	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346014	Ruby Snapper	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37354020	Teraglin	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37367010	Short Boarfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37027000	Guitarfishes	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37013003	Spotted Wobbegong	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37269002	Highfin Veilfin	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37377014	King Morwong	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37445002	Tasmanian Rudderfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37384061	Eastern Pigfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37326901	Red Bullseye	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37444005	Sailfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346913	Flagfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28925001	Giant Crab	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337053	Black Trevally	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37351018	Collar Seabream	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346028	Paddletail	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
23629001	Giant Squid	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37018007	Sandbar Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346914	Ruby Snappers	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37390790	Blue Cod	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37234000	Garfishes	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346027	Green Jobfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020036	Southern Sleeper Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37011001	Basking Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311014	Blacktip Rockcod	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346070	Sordid Snapper	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311083	Coral Rockcod	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37022002	Prickly Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37272002	Oarfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
25416033	Black Teatfish (Sea Cucumber)	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37009003	Crocodile Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37128000	Lancetfishes	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37381002	Sea Mullet	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37441009	Frigate Mackerel	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37351005	Robinson's Seabream	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA

37346901	Goldband Snapper	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28711914	Coral Prawns	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337040	Pilotfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28910001	Crystal Crab	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311021	Flowery Rockcod	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37010002	Longfin Mako	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37350003	Painted Sweetlips	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311166	Yellowedge Coronation Trout	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346030	Golden Snapper	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
25416001	Deepwater Redfish (Sea Cucumber)	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337015	Yellowstripe Scad	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282067	Whiskered Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282107	Booth's Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282083	Trawl Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37446004	Coastal Cubehead	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37357001	Bigscale Bullseye	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311060	Convict Grouper	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37086001	Australian Anchovy	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28711053	Grooved Tiger Prawn	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282102	Mother-Of-Pearl Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37464014	Common Trumpetsnout	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282013	Brushtail Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37110001	Black Loosejaw	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37335001	Cobia	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37287023	Goblinfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37464002	Shortnose Tripodfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232042	Spottyface Whiptail	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37288014	Bullhead Gurnard	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37112001	Honeycomb Scaly Dragonfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28860001	Antlered Crab	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37253002	Busakhin's Beardfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282073	Madura Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37224010	Smallhead Cod	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282100	Double-End Pipehorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282071	Upside-Down Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37035004	Bluespotted Maskray	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37042010	Black Whitefin	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37017000	Hound Sharks	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37449001	Smalleye Squaretail	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37208003	Smooth Goosefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37265003	Spotted Tinselfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37122011	Humboldt's Lanternfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282030	Mud Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311136	Bluespotted Rockcod	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282084	Prophet's Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37287004	Gulf Gurnard Perch	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282092	Western Crested Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282027	White's Seahorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020027	Smooth Lanternshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28711046	Tiger Prawn	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37361021	Grey Drummer	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282014	Deepbody Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337063	Skipjack Trevally	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
25417007	Holothurian	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232074	Spinnaker Whiptail	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282075	Beady Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28840901	Carid Prawn	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37120004	Blackedge Greeneye	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA

37004002	Broadgilled Hagfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
23300000	Cockles	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37211003	Furry Coffinfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37467009	Rusty-Spotted Toadfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28711010	[A Penaeid Prawn]	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37005000	Cowsharks	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37044002	Pacific Spookfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
23607000	Cuttlefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37467044	Prickly Toadfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311905	Coral Trout	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37382001	Striped Barracuda	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
40041002	Streaked Shearwater	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28821002	Western Balmain Bug	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37042011	Marbled Whitefin	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282098	Duncker's Pipehorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282025	Tucker's Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37287009	Orangebanded Gurnard Perch	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37461002	Banded-Fin Flounder	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37381001	Yelloweye Mullet	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311003	Barber Perch	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311078	Common Coral Trout	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37309003	Sculptured Seamoth	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37366001	Old Wife	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37004001	Longfin Hagfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282105	Bullneck Seahorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37007003	Crested Hornshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37440001	Slender Frostfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37109006	Threadfin Dragonfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020044	Endeavour Dogfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232016	Longray Whiptail	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282034	Southern Pygmy Pipehorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37287018	Soldier	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282055	Lord Howe Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37469005	Freckled Porcupinefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37141001	Beaked Salmon	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37428000	Gobies	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37349007	Short Silverbiddy	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337012	Golden Trevally	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37031001	Southern Round Skate	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37118019	Deepsea Lizardfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37287046	Deepsea Ocean Perch	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37008001	Greynurse Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37015007	Reticulate Swellshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37255002	Palefin Sawbelly	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311102	Fangtooth Perch	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28711044	Brown Tiger Prawn	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37015010	Variegated Catshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282094	Bonyhead Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37327018	Robust Deepsea Cardinalfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282019	Ringback Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282022	Mollison's Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37281001	Robust Ghostpipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
39125009	Stokes' Seasnake	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37023003	Common Sawshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37465036	Sixspine Leatherjacket	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37106002	Silver Lightfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282016	Smooth Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282078	Flatface Seahorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37210014	Rough Anglerfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA

28711910	King Prawns	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282082	Shaggy Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37287045	Whitley's Gurnard Perch	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282085	Sawtooth Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37018029	Lemon Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37281002	Ornate Ghostpipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28821901	Balmain Bugs	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37354003	Black Jewfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37467001	Barred Toadfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311040	Longfin Rockcod	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37461004	Spotted Flounder	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282050	Ocellate Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282072	Bluespeckled Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37384038	Humphead Maori Wrasse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37012003	Pelagic Thresher	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37384044	Tripletail Maori Wrasse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37465059	Yellowfin Leatherjacket	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37006001	Frill Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37013002	Collar Carpetshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282117	Sad Seahorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282086	Anderson's Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282008	Hairy Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282061	Girdled Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37330003	Goldenline Whiting	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37330007	Mud Whiting	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
40040016	Salvin's Albatross	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37384022	Brownspotted Wrasse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37215001	Prickly Footballfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37327002	Longfin Pike	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37211004	Pencil Coffinfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37085019	Bony Bream	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282047	Redbanded Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37028004	Western Numbfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
23255901	Oyster	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37384023	Rosy Wrasse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37384014	Bluetooth Tuskfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37226790	Atlantic Cod	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282120	Bigbelly Seahorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282095	Red Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28770014	[A Carid Prawn]	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37351009	Redthroat Emperor	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311004	Rosy Perch	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282026	Shorthead Seahorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37107005	Giant Hatchetfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282018	Widebody Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37439004	Sackfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37107003	Threespine Hatchetfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020026	Mandarin Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37267001	Sharpsnout Deepsea Boarfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37081002	Australian Halosaur	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37121001	Largescale Neoscopelid	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37461003	Greenback Flounder	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37460002	Smalltooth Flounder	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37085005	Sandy Sprat	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282033	Common Seahorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
23270000	Scallops	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37382002	Snook	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28786902	Scampi	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28711052	Eastern King Prawn	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37351901	Sea Bream, Snapper	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA

37400008	Yellowtail Stargazer	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37118001	Largescale Saury	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282081	Rhino Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37470001	Short Sunfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37212001	Shortfin Seabat	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37255010	Little Pineapplefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282010	Potbelly Seahorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232028	Unicorn Whiptail	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37115001	Spangled Tubeshoulder	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37465008	Brownstriped Leatherjacket	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37255005	Giant Sawbelly	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37296038	Marbled Flathead	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020505	Southern Lanternshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37439009	Longfin Gemfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
24207001	False Bailer Shell	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37114503	Longtail Slickhead	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282021	Pugnose Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37266006	Rough Oreodory	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311147	Banded Rockcod	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282006	Bentstick Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282012	Knifesnout Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
39125021	Elegant Seasnake	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37056002	Longfin Eel	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37441007	Spanish Mackerel	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28865000	Spanner Crabs	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37094001	Atlantic Salmon	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37287002	Blackspotted Gurnard Perch	0	0.0%	Bycatch	>LIM	Secondary	ERA	ERA	ERA
37277001	Trumpetfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28836003	Spiny King Crab	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311052	Slender Orange Perch	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282004	Robust Pipehorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37020015	Slender Lanternshark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37400002	Fringe Stargazer	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37224005	Largetooth Beardie	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37014001	Whale Shark	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37444002	Striped Marlin	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37467004	Balloonfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37353004	Yellowfin Bream	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37467005	Starry Toadfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346031	Tang's Snapper	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232015	Serrulate Whiptail	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282041	Tryon's Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37337039	Bigeye Trevally	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37467003	Smooth Toadfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282011	Crested Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37346000	Fusiliers, Tropical Snappers & Slopefishes	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37466001	Ornate Cowfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37464004	Largegill Trumpetsnout	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282039	Gale's Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28911020	A Swimmer Crab	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282015	Halfbanded Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282003	Gunther's Pipehorse	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37407792	Unicorn Icefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37070003	Grey Cut-Throat Eel	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282064	Tiger Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37311054	Glowbelly Seabass	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37288002	Spiny Gurnard	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282024	Longsnout Pipefish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37188010	Silver Cobbler	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37466011	Spiny Boxfish	0	0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA

37282001	Leafy Seadragon	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282005	Western Spiny Seahorse	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37372003	Bengal Sergeant	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282035	Shortpouch Pygmy Pipehorse	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28786001	Australian Scampi	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37462004	Zebra Sole	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37081003	Black Halosaur	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282099	[A Pipefish]	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37067001	Eastern Conger	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282110	Queensland Seahorse	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37282017	Spotted Pipefish	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37287048	Eastern Fortescue	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37416013	Common Weedfish	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37232035	Black Whiptail	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37384035	Yellowfin Pigfish	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
25416002	Surf Redfish (Sea Cucumber)	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28711029	Eastern School Prawn	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37103001	Australian Grayling	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
28821008	Sandbug	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37067007	Southern Conger	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37228013	Violet Cusk	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37400006	Spiny Stargazer	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA
37464010	Boomer Spikefish	0		0.0%	Bycatch	>LIM	Bycatch	ERA	ERA	ERA

21. Appendix 7: External Reviews:

Appendix 7A

O'Driscoll, R. and Doonan, I. (2015a). Review of the SESSF Fishery Independent Surveys. Part 1: Commonwealth Trawl Sector.

Appendix 7B

O'Driscoll, R. and Doonan, I. (2015b). Review of the SESSF Fishery Independent Surveys. Part 2: Great Australian Bight.

Appendix 7C

Bergh, M. (2016). Review of research, monitoring and assessment approaches in North America, South Africa, Canada and New Zealand, focusing on cost effectiveness.

Review of the SESSF Fishery Independent Surveys

Part 1: Commonwealth Trawl Sector

Prepared for Australian Fisheries Management Authority

December 2015

Prepared by:
O'Driscoll, R.; Doonan, I.

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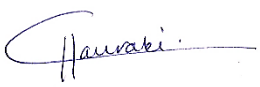
Quality Assurance Statement		
	Reviewed by:	Dr Rosemary Hurst
	Formatting checked by:	Chloe Hauraki
	Approved for release by:	Dr Rosemary Hurst

This report should be referenced as:

O'Driscoll, R.; Doonan, I. (2015) Review of the Southern and Eastern Scalefish and Shark Fishery (SESSF) Fishery Independent Surveys. Part 1: Commonwealth Trawl Sector. *NIWA Client Report* WLG2015-63.

Contents

Executive summary

1. Two of the 11 main species have indices that appear to be reliable based on results to date: John Dory and Pink Ling. Gemfish (total) also appear to have reliable estimates, but as they are winter spawners that school off bottom, a bottom trawl survey may not be appropriate. Other main species appear to have either high (>30%) estimated CVs (Blue Warehou, Blue-eye, and Silver Trevally) and/or high inter-survey variability (Blue Warehou, Jackass Morwong, Tiger Flathead, Redfish, Mirror Dory, Silver Warehou). Some of this inter-survey variability may be explained by variation in, for example, recruitment (e.g., possibly western gemfish, Mirror Dory, and Tiger Flathead) and this will become more apparent as the time series and use of the data in assessment models develop. Although Jackass Morwong shows high inter-survey variability, this has a linear trend that may represent declining abundance.

2. Common Sawshark and King Dory may also be species that are relatively well monitored by the surveys due to acceptable CVs and process error.

3. For species that have abundance estimates with acceptable levels of precision and process error, stand-alone assessments could be conducted, but stock assessment models, which include length frequency data, are likely to provide more understanding of inter-survey variability and would allow for predictions to be made.

4. Survey frequency should be dictated by monitoring and management objectives (e.g., scale of change to be detected and acted upon) and fish biology (e.g., whether long- or short-lived species); From simulations, we suggest that the risk of potentially misleading results is reduced for an annual time series.

5. The value of time series of surveys tends to increase over time, not only for individual species monitoring, but also for the development of additional indices for "environmental monitoring" (i.e., for bycatch species). Four surveys is too few to be able to assess this potential adequately.

6. Alternative approaches include CPUE analyses and more specific species-targeted surveys. We did not explore alternative survey options as they would appear to be cost-prohibitive for monitoring of the SESSF species. CPUE analyses have potential to monitor fishery performance, but are best used when they have been validated to monitor abundance. Regular updates of CPUE analyses for some key species may be useful, in conjunction with surveys, to determine relative suitability over the longer term. The trawl survey time series is too short at this stage to make meaningful comparisons with CPUE trends (which are mostly presented on finer spatial scales).

7. It is not clear that the complicated "model-based design" was required, as some of the perceived problems with a randomized stratified survey design (RSS) could have been addressed by, for example, identification and removal of areas of foul ground from the survey area.

8. Acoustic observations could be incorporated into the surveys to provide more information on inter-annual changes in vertical and areal availability of fish, by:

    - Independent estimates of total backscatter during the tows

- Estimates of total backscatter in between tows

9. It is too early in the time series to make robust decisions on whether they should be continued or not, and for which species they may be most useful. To ensure that maximum value is obtained from continuing the series, and thereby allow for a more informed decision in the future, it would be useful to address the following:

   - Which of the species are the demersal surveys method most appropriate for? For example, some species may be better assessed by alternative methods such as acoustic surveys;
   - Minimising sources of variability in abundance indices (e.g., by calibration of the survey vessels against each other);
   - Determination of factors affecting fish catchability and selectivity (in particular, seasonal changes in vertical and areal availability and aggregations; recording of maturity stage);
   - More detailed examination of variability in size frequency and abundance indices (including CPUE) both spatially (including vertical distribution) and temporally, in relation to known stock distribution and movement and juvenile areas. This will be important if robust abundance indices are to be estimated for sub-regions.

1 Background

The Australian Fisheries Management Authority has requested an independent review of two Fisheries Independent Surveys (FIS) conducted in the Southern and Eastern Scalefish and Shark Fishery (SESSF); the Commonwealth Trawl Sector (CTS) FIS and the Great Australian Bight Trawl Sector (GABT) FIS. This first reports addresses the Commonwealth Trawl Sector (CTS) FIS.

1.1 FIS Review Terms of Reference

An independent expert review of the design, utility and effectiveness of the FIS surveys for providing indices of abundance for key commercial stocks in the SESSF; standardized commercial catch rates constitute the only other index of relative abundance currently available. This review should critically evaluate and report on:

1. Whether the FIS surveys are appropriately designed, for the given cost, to provide reliable abundance indices (with acceptable CVs) for the selected target species.
2. The frequency within which surveys could be conducted (considering the impact of within year CVs and between year variations).
3. Where FIS data has been used, perhaps in addition to the main objectives, and what were the benefits? If not immediately beneficial, at what stage is it reasonable to expect that the FIS might become more valuable.
4. Whether the FIS surveys have provided acceptably reliable indices for the selected target species for use in Tier 1 assessments.
5. Whether alternative approaches (such as standardised CPUE indices, species-targeted surveys) offer acceptably reliable alternatives to FIS surveys for generating reliable abundance indices.
6. Whether FIS is effective at monitoring for target and bycatch and suggest improvements or 'add-ons' to increase utility and provide additional benefits of broader value than providing abundance indices.
7. Whether the FIS survey is useful as a stand-alone assessment.
8. Whether FIS surveys should be continued or discontinued.
    - If FIS surveys are continued, what changes or improvements should be made to improve their usefulness?
    - If FIS surveys are discontinued, what are the implications for assessments, and what are the alternatives for fishery independent surveys?
9. Whether it is appropriate to split the FIS indices into east and west abundance estimates for Pink Ling, Jackass Morwong, Mirror Dory, Silver Warehou and Blue Warehou (at longitude 147° E), and deepwater shark (at latitude 42° S).

Required Outcomes

Provision of two Final Reports presenting the results of a critical review of the FIS surveys and recommendations regarding the future continuing, cessation, revision or improvements to the surveys to maximise utility of results. This report is the first of these two reports.

2 Reviewer's Report – Richard O'Driscoll

2.1 Professional background

I have been at the National Institute of Water and Atmospheric Research (NIWA) Limited

NIWA since 2000, and in my current role as Programme Leader for Fisheries Assessment and Monitoring since 2012. My background is as a fisheries biologist. I did a PhD at the University of Otago, New Zealand, and a post-doctoral fellowship at Memorial University of Newfoundland, Canada.

I currently lead projects to estimate abundance of middle depth and deepwater fish species using trawl and acoustic surveys around New Zealand. I am also involved in biodiversity research programmes in the Ross Sea (Antarctica), around New Zealand seamounts, and on the Chatham Rise. I am an active member of the International Council for the Exploration of the Sea (ICES) Working Group on Fisheries Acoustics Science and Technology, and past convenor of the Conservation of Antarctic Marine Living Resources (CCAMLR) Subgroup on Acoustic Survey Analysis Methods. I have extensive sea-going and practical fisheries experience both in New Zealand and overseas, including three Antarctic voyages. I have an interest in using commercial fishing vessels for collection of acoustic data, and was an author of an ICES Cooperative Research Report on this topic. I also have experience in biological sampling, catch-effort analysis, otolith collection and stomach contents analysis.

2.2 Overall comments

My comments below focus mainly on the usefulness of the current SESSF survey for monitoring of target and associated species. I do not comment on whether the surveys are "cost-effective" as this is very difficult to evaluate. While costs are easily quantified, values and long-term benefits of survey time-series are dependent on societal values (e.g., social licence to operate, concerns about ecosystem structure and function, fisheries management regime) as well as the price of fish! Likewise I will leave it to my co-author, Ian Doonan, to comment on the utility of surveys for assessment.

It is clear that the design of the SESSF survey time-series has been driven largely by a requirement to involve industry participants (particularly the use of industry vessels) and to keep costs low. The major reasons given for moving away from a randomized stratified survey design (RSS) were: 1) difficulty in choosing suitable strata for multiple target species; 2) inflexibility over "logistic constraints". This has led to the complicated 'model-based design' which may not have been necessary if surveys were conducted by an independent research vessel, which did not have the same "logistic constraints". For example, with suitable acoustic equipment it is possible to survey random tow locations to determine those which are suitable for trawling before gear is damaged. Over time, "foul ground" areas can be excluded from survey strata. Patchy coverage is not an "inevitable result" of a RSS design.

However I acknowledge the potential advantages of model-based indices, and indeed within the constraints imposed, this may be the best (or only) solution.

My major concerns with the survey design are:

1. As acknowledged, the design is only as good as the underlying model. The model does not appear to provide sensible estimates for some associated species e.g., deepwater flathead.

2. Decisions about survey timing and design have seemed focused on reducing estimated CVs with less consideration of the underlying biology of the target species. Ideally, demersal trawl surveys are carried out when the species occur in the survey area and are dispersed close to the seabed. A winter trawl survey, for example, is probably not appropriate for blue grenadier, which may be aggregated in canyons (typically untrawlable with demersal gear) to spawn at that time of year. It was no surprise to me to note that summer indices of Blue Grenadier were higher and more consistent than winter indices. You can get a survey with low CV if most of the fish are outside the survey area or not vulnerable to trawling, but this does not make it a useful abundance index!

3. Demersal trawl surveys are usually not appropriate for schooling species (e.g., Silver Warehou, Blue Warehou), or those that occur away from the seabed (e.g., Silver Trevally, alfonsino). This is because of the process error due to changes in fish availability, which typically leads to highly variable estimates between years that do not track abundance.

4. There is potential bias in abundance estimates caused by trawl surveys avoiding certain areas (rough ground, MPAs) if fish preferentially occur in these areas. Interpretation of abundance indices assumes that the proportion of the population in the untrawlable area remains constant over the survey series. I am not sure that this bias is any worse for the model-based design than for a RSS design, but the model-based design (and the lack of spatial plots showing tow locations) makes it more difficult to evaluate the proportion of the surveyed area that cannot be sampled.

5. Having different trawl gear and different vessels in different areas is not ideal in terms of trawl standardisation, but may not be able to be avoided here. I'd be interested to know if there was any detected vessel effect with the use of *Game Reason* (2010 and 2012) versus *Francesca* (2008) in the NSW sector for the summer surveys given that power (hp) values are so different? In New Zealand, we have also found that winch configurations (e.g., locked versus 'auto-trawl') can have an influence on catch rates, particularly in poor weather. I note that vessel use has been consistent in winter surveys and this should be encouraged to continue (but not easy to guarantee under a vessel tender process!). I would also like to be reassured that there are detailed protocols about what is accepted as a "valid tow" (e.g., weather constraints, ensuring ground contact and that gear is not 'flown' etc.).

6. I don't like the idea of allowing industry participants to choose tow length with only a minimum constraint (2 hours). Why not just choose a standardised tow duration, so that this factor is taken out of the model?

7. Four surveys is about the minimum number required to start to evaluate survey usefulness for monitoring. In 2013, the choice seemed to be to switch from biennial summer and winter surveys to annual winter surveys, so how have you ended up with only biennial winter surveys? Cost again? Clearly the less frequently you do surveys, the longer the period required to generate the number of surveys necessary to form a useful time series (apologies for stating the obvious!).

I commend the quantity of data collected. Quantifying and measuring such a large number of fish each survey would have been a difficult task for the single fisheries technician onboard each vessel. Some minor suggestions:

1. What was the threshold between catch weights being "measured or estimated"? Were larger catches estimated and smaller ones weighed? There seems to be room for error here?

2. Was bottom duration recorded from LOTEK TDR or based on skipper estimates? How was trawl bottom contact and gear performance assessed? I come from a background in NZ deepwater fisheries where acoustic net monitors are commonly used to assess gear performance. We also deploy bottom contact sensors on inshore trawl surveys to assess ground-gear contact. Were there specifications about warp:length ratios and suitable weather conditions for trawling, or were these left to discretion of industry skippers?

3. Trawling was restricted to daytime to avoid diurnal bias, but the same hours 0500-1800 were used for winter and summer surveys. Is it really daylight at 0500 in your survey area in winter?

4. It might be useful to record maturity observations (macroscopic gonad stages or gonad weight) on key species to help inform appropriateness of survey timing.

5. Recording echosounder (acoustic) data during trawling can help inform survey results based on aggregations of fish above the seabed.

2.3 Comments on specific Terms of Reference

ToR 1: Were the FIS surveys are appropriately designed, for the given cost, to provide reliable abundance indices (with acceptable CVs) for the selected target species?

As noted above, the model-based survey design appears driven largely by the logistical constraints imposed by use of industry vessels. Given these constraints, the model-based design approach appears appropriate and target CVs reasonable. I agree with the general 'rule of thumb' that annual CVs need to be less than 30% for the survey to be useful, and annual CVs less than 20% should be targeted for key species. Of the 11 main species in winter surveys average CVs less than 20% (over 4 years) are only achieved for John Dory, tiger flathead, Pink Ling, and Silver Warehou. Average CVs of 20-30% were achieved for Jackass Morwong, gemfish (total), redfish, and Mirror Dory (see Table 1).

However CVs should not be the only consideration when evaluating whether the abundance index is reliable. Other considerations are whether the survey area and timing is appropriate (availability) and whether the fish are close to the seabed (vulnerability). These factors combine to influence the survey catchability, which Knuckey et al. (2013) refer to as the "process error". The fundamental assumption of using trawl surveys as a relative index of abundance is that the catchability is consistent between years (Francis et al. 2001). It is possible to make some *a priori* predictions about trawl survey reliability. As noted in my general comments, trawl-based abundance indices work best when the species of interest occurs in the survey area and is dispersed (i.e., not aggregated) close to the seabed. Knowledge of a species' distribution and biology can provide clues about whether a trawl survey is likely to be appropriate.

There are also a number of ways to evaluate the assumption of constant catchability from survey data. These include looking at the variability in abundance indices between surveys, evaluating whether length modes that may represent specific ~~years~~year ~~classes~~classes' track between ~~survey~~surveys in a manner that is consistent with known growth, and looking for correlated increases and decreases of species groups.

To evaluate variability in abundance indices between surveys I have sometimes found it useful to calculate CV from the annual estimates as though they are independent estimates of the mean of the same underlying population assuming this has not changed over time (I call this CV2) and compare this to the arithmetic average CV of the survey estimates (CV1). If CV2 is less than or equal to CV1 then the annual variability in abundance indices is within the variability expected purely due to sampling error (if the underlying population has not changed). If CV2 is greater than CV1 then either the variability due to process error is greater than the sampling variability (if the underlying population has not changed) or the underlying population has changed over time. As noted by Knuckey et al. (2013), the amount of variability due to changing population abundance can be informed by knowledge of population biology, where short-lived species are expected to vary more between years than long-lived species due to variable recruitment. This can sometimes be determined from looking at length frequencies.

Looking at values in Table 1, I would be concerned that of the 11 key species, winter surveys potentially have underlying process error for Blue Warehou, Jackass Morwong, Tiger Flathead, Redfish, Mirror Dory, and Silver Warehou. This can also be seen from abundance plots in Figure 23 of Knuckey et al. (2015) which show high inter-survey variability for these species. For example, there were very low abundance estimates for Blue Warehou and Jackass Morwong in 2014 compared to other surveys. Similarly, tiger flathead were high in 2012, redfish were low in 2012, and abundance indices Mirror Dory and Silver Warehou were all over the place. None of this variability between surveys was easily explained by variable recruitment (based on LF plots).

Table 1: Comparison of estimates of CVs from winter surveys 2008 - 14. CV1 is the arithmetic mean of survey CVs. CV2 is the CV estimated by treating survey abundance estimates as independent samples of the population. Data from Table 7 of Knuckey et al. (2015). Species in bold are the 11 main species .

Species	CV1	CV2	CV2/CV1
Blue Warehou	**0.40**	**0.50**	**1.25**
Jackass Morwong	**0.22**	**0.29**	**1.33**
John Dory	**0.17**	**0.14**	**0.85**
Gemfish	**0.23**	**0.11**	**0.47**
Tiger Flathead	**0.11**	**0.14**	**1.23**
Pink Ling	**0.16**	**0.04**	**0.27**
Silver Trevally	**0.88**	**0.58**	**0.66**
Redfish	**0.26**	**0.38**	**1.47**
Blue-eye	**0.53**	**0.31**	**0.60**
Mirror Dory	**0.25**	**0.49**	**1.93**
Silver Warehou	**0.17**	**0.34**	**2.08**
Orange Roughy	2.25	0.71	0.31
Royal Red Prawn	0.42	0.71	1.70
Ocean Perch	0.18	0.48	2.60
Alfonsino	0.53	0.99	1.90
Ribaldo	0.49	0.25	0.52
Dogfishes	0.47	0.39	0.82
Gummy Shark	0.23	0.29	1.24
School Shark	0.38	0.46	1.22
Deepwater Flathead	0.34	0.49	1.46
Blue Grenadier	0.26	0.28	1.11
Common Sawshark	0.16	0.05	0.30
Frostfish	0.38	0.53	1.41
King Dory	0.28	0.10	0.36
Red gurnard	0.38	0.29	0.79
Greeneye Dogfish	0.74	0.22	0.30
Speckled Stargazer	0.31	0.25	0.81

The above concerns are indicative only, as the time-series is still relatively short. To provide reassurance that the survey is actually monitoring abundance for key species requires a longer series that can be demonstrated to track changes in underlying populations (caused either by fishing or recruitment) – observed as biologically explainable changes in indices which are consistent with observed size composition and fish biology (natural mortality etc.). In practice this is often determined by whether assessment models (which incorporate other sources of information) can be made to fit trawl abundance indices with reasonable assumptions about process error and without patterns in residuals.

In some instances, changes in survey catchability (process error) are observed as consistent changes in abundance across a range of species. To test for this, Francis et al (2001) proposed an extreme catchability rank test. This method ranks the survey years in order of increasing biomass index for each species and then compares mean rank across all species with expected mean rank. 'Extreme' catchability years are defined as those with probability less than 5% that the deviation of the mean rank from expected could be observed by chance if there was no between-species correlation. I applied this test to the 11 key species in the four winter surveys (Figure 1), and found no evidence for correlated changes in catchability between species in the four winter surveys to date.

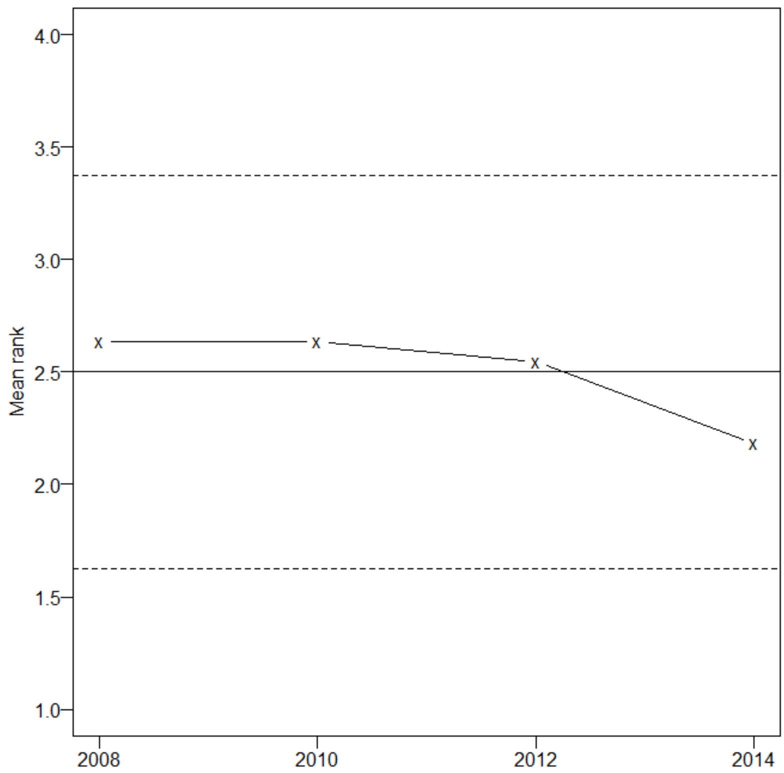


Figure 1: Francis extreme catchability test for key 11 species in winter surveys 2008 - 14. Crosses show mean species rank of species in each survey year. Horizontal lines show expected mean rank with 95% confidence intervals if changes in species abundance are uncorrelated. Values falling outside these confidence intervals are considered to indicate 'extreme catchability'. Data from Table 7 of Knuckey et al. (2015)..

ToR 2: The frequency within which surveys could be conducted (considering the impact of within year CVs and between year variations).

The survey series started as biennial summer and winter surveys and appears to have switched to biennial surveys in winter only. Knuckey et al. (2013) proposed switching to annual winter surveys, so presumably the decision to stick with biennial timing (and therefore reduce the total number of surveys by half) comes back to cost?

The choice between summer and winter surveys should be based on fish biology. As stated above, demersal trawl surveys are ideally carried out when the species occur in the survey area and are dispersed close to the seabed. Conversely, trawl surveys are not usually suitable when fish are aggregated or have migrated elsewhere (e.g., for spawning). Those involved with these fisheries will understand the local biology better than me, but based on timing of spawning in New Zealand, I would have thought that a winter survey would be more appropriate for summer spawners like Jackass Morwong and John Dory, and less appropriate for winter spawners like gemfish and blue grenadier? No survey timing will be ideal for all key species, so my recommendation is to pick the timing that is most appropriate for the most important (commercially valuable?) species and then stick to it. The decision seems to have been made that this is winter?

The frequency of surveys should depend on: 1) expected time-scale of changes in abundance; and 2) the desired precision to detect change. In general, it is more important to have frequent surveys for fast growing short-lived species, where populations change rapidly in response to variable recruitment, than for long-lived species for which the expected rate of underlying population change is slower.

As a simple illustration of the effect of reducing survey frequency on the ability (precision) to monitor abundance of a single species, I recently carried out a simulation experiment to investigate timing of New Zealand trawl surveys. Consider a generic species, A, which is indexed by the trawl survey. Assume that we have a relative precise estimate of current (2014) vulnerable biomass based on all previous work to date (I assumed a CV of 10%). Further assume that the underlying population of species A decreases linearly over the next 5 years so that B_{2019} = 50% B_{2014} (Figure 2). A reduction of 50% was arbitrarily chose as something that we would (or at least should) be concerned about. I then generated a simulated survey biomass estimate for each year based on sampling the model population with a survey CV of 25%. The trend in abundance and the estimated ratio of B_{2019}/B_{2014} were then estimated from available surveys by simple linear regression. I modelled two survey frequencies: annual (2015–2019), and biennial (2016 and 2018) (Figure 2).

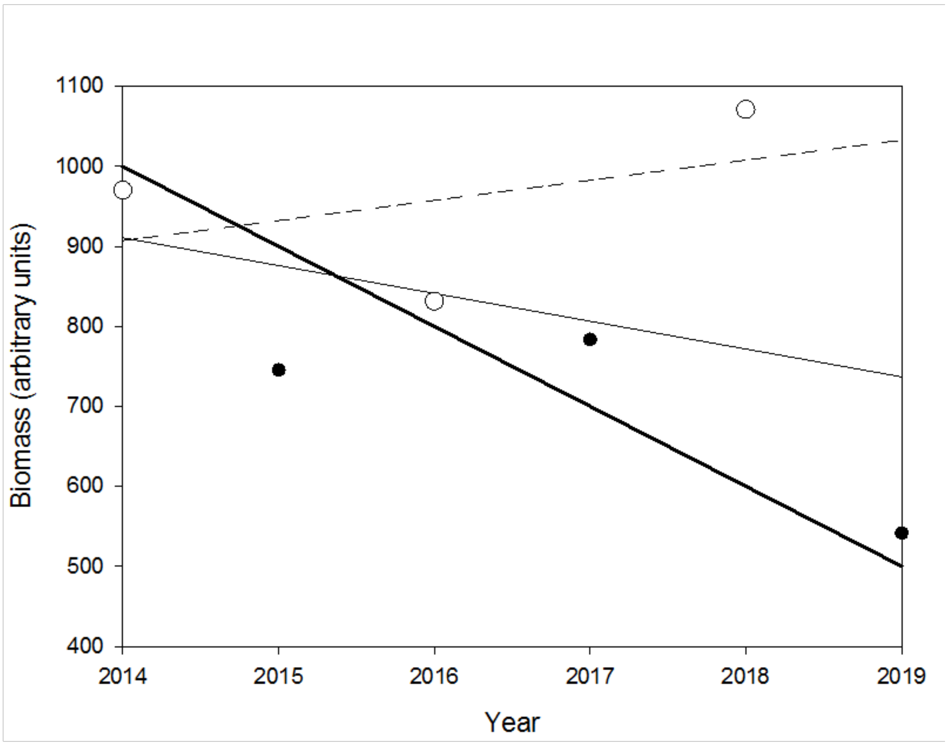


Figure 2: Example of one outcome (of 1000) from a simulation experiment to illustrate effect of survey frequency on ability to estimate trends in abundance. Underlying (true) population abundance is shown as thick solid line. Starting biomass (B2014) was estimated with 10% CV. Survey biomass estimate for each subsequent year based on sampling the model population with a total survey CV of 25%. Thin solid line shows linear regression through all data points (solid and hollow circles) representing annual surveys. Dashed line shows regression through hollow circles only, representing biennial survey.

The estimated distributions of ratios of B_{2019}/B_{2014} from these simulations is given in Figure 3. With annual surveys, the 5%–95% confidence intervals (CI) on B_{2019}/B_{2014} was 0.31–0.73. With biennial surveys, the CI was 0.18–0.86. In 8.2% of biennial simulations the population was estimated to decrease by less than 20% over the 5 years ($B_{2019}/B_{2014} > 0.8$), and in 1.4% of biennial simulations the population was estimated to increase ($B_{2019}/B_{2014} > 1.0$). An example of such an outcome is given in Figure 2. The risk of such potentially misleading results is greatly reduced for an annual series (Figure 3).

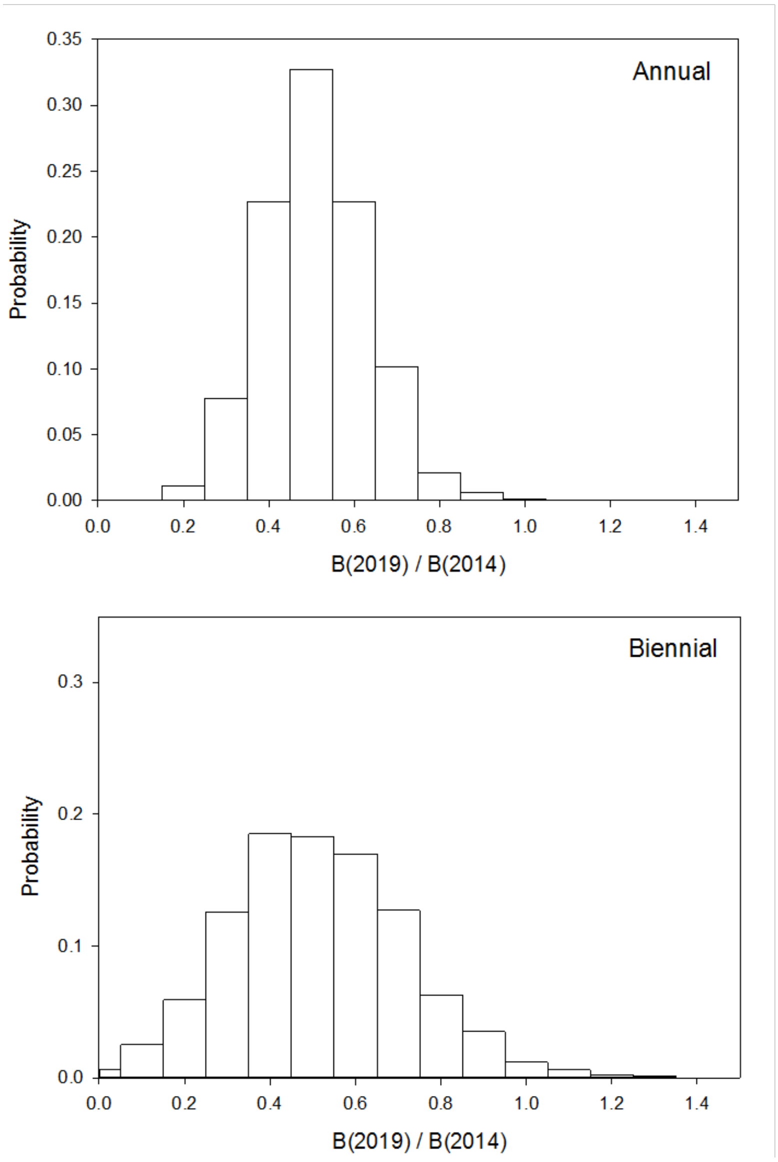


Figure 3: Estimated ratios of B2019/B2014 from 1000 runs of a simulation experiment . To illustrate effect of survey frequency on ability to estimate trends in abundance. Actual population trend was a 50% decline in abundance (i.e., B2019/B2014 = 0.5)..

Other scenarios can easily be simulated with different assumptions about CV on $B_{current}$, changes in population biomass, survey CV, and survey frequency. Although this is a simplistic representation, this is the type of exercise that could be carried out to quantitatively evaluate loss of information and increased risk from different survey frequencies.

ToR 3: Where FIS data has been used, perhaps in addition to the main objectives, and what were the benefits? If not immediately beneficial, at what stage is it reasonable to expect that the FIS might become more valuable?

Because many other species are caught and measured, the FIS time-series may provide an "ecosystem monitoring" role in the future (e.g., Tuck et al. 2009). For this reason, non-target species should continue to be quantified. Size-based metrics provide a broader range of ecosystem indicators than those based only on abundance (Tuck et al. 2009), so consistently measuring non-target species is also valuable (if time permits).

Like all time-series metrics the survey series will become more valuable over time. For New Zealand deepwater surveys, it has taken over 20 years to realise the value of some of our trawl time-series (e.g., O'Driscoll et al. 2011). It is very difficult to quantify "value" of long-term environmental monitoring programmes. For example, how long does a temperature record need to be to estimate climate change?

ToR 4: Whether the FIS surveys have provided acceptably reliable indices for the selected target species for use in Tier 1 assessments?

See my comments under ToR 1 above.

ToR 5: Whether alternative approaches (such as standardised CPUE indices, species-targeted surveys) offer acceptably reliable alternatives to FIS surveys for generating reliable abundance indices?

The model-based FIS design is like super-standardised CPUE. If FIS isn't able to generate reliable abundance indices for the key species, then it is unlikely that CPUE indices will, although CPUE indices are less time constrained and may cover more appropriate seasons. Species-targeted surveys may be more effective for some species (e.g., winter acoustic surveys of spawning blue grenadier), but the only realistic alternative to providing abundance indices for a suite of species would be a randomised stratified trawl survey, which seems to have been ruled out because of the "logistical constraints" and cost (e.g., the non-availability of a suitable fisheries research vessel).

ToR 6: Whether FIS is effective at monitoring for target and bycatch and suggest improvements or 'add-ons' to increase utility and provide additional benefits of broader value than providing abundance indices?

As noted above, the FIS series potentially provides information on a wide range of species. However it is apparent that the model-based design does not appear to be providing reliable abundance indices for some species. For example, I don't get how estimated deepwater flathead biomass can drop from 11630 (tonnes?) to 4914 from 2008 to 2010 when catches increased (from 1787 kg to 1849 kg). That is I understand that this can occur in theory, but it rings alarm bells! When a species is rarely caught it is unlikely that the model does well at predicting catch rates, and therefore may not be appropriate for estimating abundance.

Plots comparing the covariate coverage with the actual survey (Figure 3 in Knuckey et al. 2013) are useful, but I found the deviation between the planned and actual coverage a bit disturbing! I would like to see this plot for all surveys. I am not sure what Figure 2 of Knuckey et al. (2015) is comparing as there was no summer survey in 2014? I would also find maps showing spatial distribution of catch rates for key species (as expanding symbol plots) very informative as part of the annual survey reports. These would be useful to visually assess whether spatial distribution is stable over time (outside the statistical spatial predicted model).

If logistically possible (and I doubt it with only one fisheries technician on board) it would be useful to record maturity observations (macroscopic gonad stages or gonad weight) on key species to help inform appropriateness of survey timing.

Recording echosounder (acoustic) data during trawling can help inform survey results based on aggregations of fish above the seabed. If the survey vessels have suitable echosounders (e.g., Simrad ES60/ES70) then these data should be logged during the survey. In New Zealand, acoustic data collected on trawl surveys have been used to provide estimates of the trawl catchability (O'Driscoll 2003), and to estimate abundance of mesopelagic fish (McClatchie & Dunford 2003).

ToR 7: Whether the FIS survey is useful as a stand-alone assessment?

If FIS surveys can be demonstrated to track abundance with acceptable precision, then these may be useful for stand-alone assessment through some kind of decision-rule management strategy. The biggest obstacle is that survey indices are variable (due to sampling and process error) and this tends to lead to undesirable fluctuations in catch limits if these are linked directly. Assessment models tend to smooth out this variability and also allow predictions/predictions and risk estimation (especially if the underlying models have other information on biological parameters and recruitment/age composition).

ToR 8: Whether FIS surveys should be continued or discontinued?

- *If FIS surveys are continued, what changes or improvements should be made to improve their usefulness?*
- *If FIS surveys are discontinued, what are the implications for assessments, and what are the alternatives for fishery independent surveys?*

In my judgement, it is still too early to determine the usefulness of the FIS surveys. As I have stated, to provide reassurance that the survey is actually monitoring abundance for key species requires a longer series that can be demonstrated to track changes in underlying populations (caused either by fishing or recruitment) – observed as biologically explainable changes in indices which are consistent with observed size composition and fish biology.

It is perhaps unfortunate that discussion about appropriateness of the underlying statistical survey design may have distracted concerns about whether a demersal trawl survey is even appropriate for the species of interest, and also issues about survey timing in relation to life history (e.g., timing of spawning).

With unlimited budget, it would definitely be possible to do a better and more useful survey. In reality, what is done is determined by available budget, vessels, staff, and logistics, and I am not sure that you could do any better than what has already been achieved within these constraints.

ToR 9: Whether it is appropriate to split the FIS indices into east and west abundance estimates for Pink Ling, Jackass Morwong, Mirror Dory, Silver Warehou and Blue Warehou (at longitude 147° E), and deepwater shark (at latitude 42° S).

See Ian Doonan's comments.

2.4 References

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3 Reviewer's Report – Ian Doonan

3.1 Professional background

I started at Fisheries Research, MAF, in 1978, which was then taken over by NIWA in 1995. My current role is Group Manger, Fisheries Modelling. I did a PhD at the University of Canterbury, New Zealand, and I was a NIWA consultant to the Marine Institute, Ireland, in 2005-07. During that period, I represented Ireland at several ICES working groups (deepwater species, herring, survey design, and southern demersal species).

I have broad experience in the quantitative side of fisheries: designing and analysis of dredge, trawl, and acoustic surveys; estimating parameters using statistical techniques, stock assessments on deep deepwater species, design and analysis of experiments, and developing new methods of analysis and surveying. I have lead or supervised all stock assessments on black oreo and smooth oreo since the mid-1990s, and developed, and lead or supervised acoustic and trawl surveys on orange roughy and oreos since the late 1990s.

3.2 Overall comments

There was an oblivious agenda to use industry vessels for this survey and also not to use random stratified designs (RSS). At first sight, the model based design used looks attractive and seems to have solved the issue about designing and analysing multi-species surveys. However, on closer examination, I think it has some unfavourable features which makes me wary of using it as the analysis to apply to the survey data.

Summary of the FIS survey design:

- The original tow positions were selected randomly (via depth and coastal position), but many had to be shifted to find trawlable ground. These positions were then reused for all the following surveys apart from substituting in 12 shallow sites in 2010;
- Fixed factors estimated from CPUE 2000-05 data are applied and a smooth change in coastal effect estimated using that year's survey data. This accounts for distributional shifts along the coast and changes in abundance by year;

- The model is then used to predict catch rates on a spatial grid covering the survey area and these are integrated to get the relative abundance.

The key feature is the initial randomisation to select tow positions which is potentially very valuable for monitoring species abundance. The survey is not truly a fisheries independent survey since depth and other fixed effects are derived from CPUE in one six year period. A problem is that three different vessels and two net types were used in each survey which would require producing a series for each vessel until inter-vessel differences can be resolved. To assess survey suitability, I have looked at the species abundance CV by survey since this will be indicative of overall performance in a stock assessment analysis when all three series are included.

The model-based CV seems to be overly sensitive, reducing the number of tows (Knuckey et al. 2013). For example, tiger flatheads has a CV of ~14% which increases to 22% when 10% of tows in the deep strata are removed (perhaps about 5% of the total tows). For random stratified sampling (RSS), decreasing the number of tows by 10% means that the CV should increase by 5% ($^1/_{\sqrt{0.9}}$), and for a 5% reduction in tows the CV would increase by 2.5%. The factor of 22/15 = 1.6 suggests that something is amiss with these estimates.

Alfonsino in 2014 had a relative abundance larger by 2 orders of magnitude to the next largest, but its CV (38%) was the lowest in the series. I would expect that the CV for 2014 to be much larger than the other years (but this is based on random stratified surveys is experience). This modelling approach is certainly not intuitive to me.

Bias vs trends in bias

There was a concern about bias in the abundance estimate in the design documents (Knuckey et al. 2013). Bias in surveys is called catchability which can be estimated in the stock assessment model and it is usually assumed to be constant. It covers fishing efficiency, the fraction of the stock on untrawlable grounds, and any other constant biases (e.g., vessels). Annual variations of catchability about a mean value is allowed (process error), but trends in bias or catchability are not since they get captured into the abundance trend.

Bias in RSS was one reason for discarding the method (Knuckey et al. 2013). When positions are randomised for each survey, any “bias” in one year goes into the CV for the survey. However, for fixed tow position in each survey, the bias above is fixed into the catchability.

Since the FIS is a fixed tow survey, we require that the true effects in the offsets of the reduced model (mainly depth) remains constant from year-to-year. The same applies for the proportions of the stock on untrawlable grounds and fishing efficiency (partly or wholly taken care of by using the same nets and trawl protocols in each stock area). If there is a change in the vessels used, then there will be a one-off change in catchability. Since the FIS survey used fixed stations, you do not need the model since any bias from offset depth effects will also be fixed into the catchability. Time-of-day effects seems to be small relative to the spread of values and should not be important unless you can carry out each tow at the same time of day in each survey.

Distributional changes in the coastal effect are captured in the coastal-tear effect ($s_{X.Y}(x){:}y_i$) that is estimated for each year and so changes along the coast are not a problem.

Fixed depth effect (offset)

The depth effect is for that which existed in 2000-05. Changes in this effect will bias the abundance estimator and this could be either process error or a trend for evolving changes over a few years to occur. For many species, the depth profile is related to size (age) with large fish being deeper, so it can potentially change when there is a large recruitment pulse, which would start shallower (I presume) and travel deeper with time, or natural mortality changes for a period of time, which will alter the age distribution and hence the depth profile, or by fishery induced changes, such as domed selectivity so that deeper waters become relatively more populated.

The depth effect may be biased from vessel effects which were not consistent when estimating this effect from the CPUE data. Vessel effect is regularly one of the strongest effects in NZ CPUE analyses. It also appears to be strong for some SESSF species (Sporcic 2015). There is also an effect from comparing targeted tows on a species to those caught as bycatch. It is much more likely that target tows will have a higher catch rate than by-catch tows and if targeting has a depth component, then these differences will be captured into the estimated depth effect.

The coastal-year interaction comes from averaging tow data as adjusted by depth and the fixed coastal mean and other effects and estimating a new coastal effect for that year. For each coastal slice the coastal-year effect is the average shift over the data points in that slice (but constrained by the smoothing penalties) given the adjustments for depth and other effect, but it takes no account of spatial spread implicit in the depth profile or the sampling densities by depth. When the depth effect is unchanged, this procedure yields the correct values. However, if the depth effect has a bias or has shifted, then this procedure gives a biased value which is weighted towards the depths where most tows occur.

This really needs some work to see if these effects are significant or not, and how extreme do they have to be before they induce a temporary trend.

Since the positions are fixed, an alternative method that makes no assumptions apart from constant mean catchability (net efficiency and proportion in untrawlable ground) is to calculate the weighted mean catch rate where the weights are the area of the tile that surrounds each survey point (formed by irregular tessellation across the survey with each tile containing only one survey position). The analysis would then be independent of the conditions in 2000-05 and more transparent on how the survey data is used.

3.3 Comments on specific Terms of Reference

ToR 1: Whether the FIS surveys are appropriately designed, for the given cost, to provide reliable abundance indices (with acceptable CVs) for the selected target species.

The design is appropriate since tow positions were initially chosen randomly. Depending on how replacement tows were chosen for those on untrawlable ground, there may be some issues for those that were left to skippers to find (i.e., using known good tows as has happened in New Zealand south Chatham Rise oreo surveys). It is hard to know if CVs are reasonable since the survey needs to be split by area, especially the heavy-net data, but the whole area CV should be a guide for when all series are used in a model.

For the 11 main species in the whole survey (winter), median estimated CVs below 20% were obtained for John Dory, Tiger Flathead, Pink Ling, and Silver Warehou. Median CVs of 20-30% were obtained for Jackass Morwong, Gemfish (total), Redfish, and Mirror Dory.

Observations on CVs include:

- The Silver Warehou estimated CV appears to be badly underestimated or has large process error and so it would not be suitable (CV from survey points assuming a flat trend is 69% (SPcv)) (Knuckey et al. 015);
- For Tiger Flathead process error or its ~14% estimated CV is underestimated for some reason (SPcv 26%), but the SPcv is acceptable;
- Mirror Dory and Jackass Morwong have one or two odd values and so may be problematic in a stock assessment;
- Redfish has too much process error (SPcv of 76%);
- Blue Warehou, Silver Trevally and Blue-eye have unacceptably large CVs (>40%)
- Total Gemfish has median CVs (19–29%) but CV on the eastern and western indices are higher (western 30–44%; eastern 58–76%).

Consequently, it is a mixed result since only 5 of the 11 species have indices that are reliable based on results to date: John Dory, Tiger Flathead, Gemfish (total), PinkLling, and Jackass Morwong. The only way to really know is to put them into a stock assessment and look at the estimated process error and other diagnostic of fit results. It really needs contrast in abundance so that catchability is better estimated and abundance can respond to changes in catch levels. In addition, gemfish are winter, off-bottom spawners and may not be reliably sampled by winter bottom surveys.

ToR 2:The frequency within which surveys could be conducted (considering the impact of within year CVs and between year variations).

This depends on how well you want to monitor and against what scenarios (e.g., detecting a halving or doubling of biomass within an 80% probability), the quality of other data collected, and the response time for management. *See* Richard O'Driscoll's comments.

ToR 3: Where FIS data has been used, perhaps in addition to the main objectives, and what were the benefits? If not immediately beneficial, at what stage is it reasonable to expect that the FIS might become more valuable?

See comments above. The FIS surveys have been used in Pink Ling assessment (2008, 2010, and 2012) and appeared to fit well. However, the assessed stock has a flatish trajectory (relative to sampling errors) and with three points it is hard for the series to have any influence against the CPUE series which has many more points and is fitted to a major decline in abundance, but at least the FIS index did not contradict the assessment. As with all time-series, it needs a longer series along with more contrast in abundance.

ToR 3: Whether the FIS surveys have provided acceptably reliable indices for the selected target species for use in Tier 1 assessments?

See my comments under ToR 1 above.

ToR 4: Whether alternative approaches (such as standardised CPUE indices, species-targeted surveys) offer acceptably reliable alternatives to FIS surveys for generating reliable abundance indices?

CPUE indices are generally used if you cannot afford a survey. In my experience, CPUE often have systematic residuals indicating poor fits (such as being too steep a decline that cannot be modelled given the biology of the species). For the species that performed poorly in the FIS surveys, I doubt that a trawl RSS survey would be better since process error problems would still remain for any practical survey effort (i.e., cost). Acoustic survey may work for aggregated species, but you would need enough effort to guarantee seeing 10 or more such aggregations randomly or know where they congregate for spawning.

ToR 5: Whether FIS is effective at monitoring for target and bycatch and suggest improvements or 'add-ons' to increase utility and provide additional benefits of broader value than providing abundance indices?

Common Sawshark and King Dory are candidates. They would also need age and length frequencies (for selectivities and monitoring of recruitment). Other species are too variable and some have far too few tows where they are caught to give confidence they are monitoring abundance.

ToR 6: Whether the FIS survey is useful as a stand-alone assessment?

For the species indicated above, the FIS could be used as a stand-alone assessments. But, you would first need to see contrast in the abundance for them to be really useful. Currently, most indices are flatish (relative to CV) which means that the only information on virgin abundance is for the lower bound which is based on the lowest virgin abundance that can support observed catch in the model.

ToR 7: Whether FIS surveys should be continued or discontinued?

- *If FIS surveys are continued, what changes or improvements should be made to improve their usefulness?*
- *If FIS surveys are discontinued, what are the implications for assessments, and what are the alternatives for fishery independent surveys?*

It is too early to decide. At the series current length, they are not that useful, so discontinuing the series will mean little to current assessments. The problem for all survey series is maintaining them for long periods of time. It is all too easy to stop surveys in the early stages because they do not appear to be useful in the short term. When reinstated later, changes in the intervening period can create problems in the assessment. The longer the series is, the more valuable it becomes.

The vessels should be calibrated against each other. This can be done by interlacing a strip of tows at the boundary of each vessels' area, i.e., neighbouring tows in the strip are done by different vessels (perhaps at similar times of day).

Collecting data on net efficiency and the proportion of fish in untrawlable grounds will allow an informed prior to be used in the stock assessment, which will help the assessment model to use the survey abundance estimates.

The working group should consider revising the survey abundance calculation to weight each tow's data by the area of the tile that supports it. This has the equivalent purpose as the predict-integration step of the model-based estimation, which accounts for survey density effort by area. Whatever bias is introduced by the fixed configuration of tow positions is fixed into the catchability. This would remove the assumptions used in the model and make it independent of the 2000-05 CPUE data, and be more transparent in the use of the survey data.

ToR 9: Whether it is appropriate to split the FIS indices into east and west abundance estimates for Pink Ling, Jackass Morwong, Mirror Dory, Silver Warehou and Blue Warehou (at longitude 147° E), and Deepwater Shark (at latitude 42° S).

In general, any of the indices can be split at any place since a catch rates are predicted on a grid and these are integrated. The part of the grid within each sub-area can also be integrated on their own to provide indices for each part. Note that the CVs will be larger for the smaller areas. A good example of this is for Gemfish, which has a median CV for the total survey of 21%, but for the eastern and western Gemfish, the median CVs are 67% and 38%. The western Gemfish is marginal and when we add in process error, the CV increases to 67%. Hence, the split can be made but, for each stock, you will then need to look at the CV and process error to see if they are useful.

The key issue here is whether the biological data support the split into separate stock units. Size frequency information for Jackass Morwong, Mirror Dory, Pink Ling, and Silver Warehou do show some regional differences, but it is unclear if this just represents juveniles occurring more in one area than another. There did not appear to be enough data for one of the Blue Warehou areas (from the length frequencies) to enable it to be split.

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Review of the SESSF Fishery Independent Surveys

Part 2: Great Australian Bight

Prepared for Australian Fisheries Management Authority

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Quality Assurance Statement		
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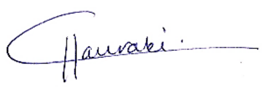	Formatting checked by:	Chloe Hauraki
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Contents

Tables

Figures

Executive summary

1. The random stratified survey design is appropriate to monitor the two target species, flathead and redfish; good features include randomised positions, station allocation by strata, strata design based on CPUE, repeating the ground coverage and trip twice. The CVs are good and the process error appears to be modest, so overall the combined error is low enough for reliable monitoring. Flathead indices make an important contribution to the assessment model. The fixed-site design may introduce some bias (if there are persistent strong local effects, or day/night effects), but reported CVs are probably appropriate.

2. Re-evaluation of stratum boundaries for the target species would be useful to determine if they are appropriate, as well as determination of optimal station allocation (e.g., as described by Francis 2006). This may result in cost efficiencies by being able to reduce the number of stations required and, potentially, survey at night only.

3. Survey gear standardisation would be enhanced through the use of sensors to monitor bottom contact and gear spread (area swept). Recording echosounder data can help inform interpretation of survey results (e.g., vertical availability to the gear). Problems with gear in the 2015 survey suggest that Trip 2 data only are best for assessment purposes.

4. The recent large decline in abundance of the target species (50% for flathead, 72% for redfish) suggests that a survey frequency of more than once every four year should be considered. The problems with the 2015 survey gear suggest that a repeat survey in 2016 would be beneficial (although there was no clear evidence of a lower catchability in this year). The cost of more frequent surveys may be able to be balanced, to some extent, against better optimised sampling (see #3 above). The appropriateness of survey timing was not evaluated.

5. The survey series is providing average CVs of less than 30% for the nine other main species (six had average CVs less than 20%), which is suitable for monitoring. Broader ecosystem monitoring would also appear to be feasible.

6. The two target species have abundance estimates with acceptable levels of precision and process error and stand-alone assessments could be conducted. However, stock assessment models, which include length frequency data, are likely to provide more understanding of inter-survey variability and would allow for predictions to be made.

7. CPUE analyses for flathead have large error bars, which make them a weak data series, and they appear to have limited value compared with survey abundance indices and age and length data. Redfish were unable to be evaluated.

8. Our assessment is that the surveys are providing useful abundance indices and should be continued, for target and associated species. Suggested improvement include optimisation of the design which should improve performance and decrease costs, and improved monitoring of net performance. Determination of factors affecting fish catchability and selectivity would also be beneficial.

1 Background

The Australian Fisheries Management Authority has requested an independent review of two Fisheries Independent Surveys (FIS) conducted in the Southern and Eastern Scalefish and Shark Fishery (SESSF); the Commonwealth Trawl Sector (CTS) FIS and the Great Australian Bight Trawl Sector (GABT) FIS. This second report addresses the Great Australian Bight (GABT) FIS.

1.1 FIS Review Terms of Reference

The terms of reference are the same as those for the CTS report (O'Driscoll & Doonan 2015) and repeated below.

An independent expert review of the design, utility and effectiveness of the FIS surveys for providing indices of abundance for key commercial stocks in the SESSF; standardized commercial catch rates constitute the only other index of relative abundance currently available. This review should critically evaluate and report on:

1. Whether the FIS surveys are appropriately designed, for the given cost, to provide reliable abundance indices (with acceptable CVs) for the selected target species.
2. The frequency within which surveys could be conducted (considering the impact of within year CVs and between year variations).
3. Where FIS data has been used, perhaps in addition to the main objectives, and what were the benefits? If not immediately beneficial, at what stage is it reasonable to expect that the FIS might become more valuable.
4. Whether the FIS surveys have provided acceptably reliable indices for the selected target species for use in Tier 1 assessments.
5. Whether alternative approaches (such as standardised CPUE indices, species-targeted surveys) offer acceptably reliable alternatives to FIS surveys for generating reliable abundance indices.
6. Whether FIS is effective at monitoring for target and bycatch and suggest improvements or 'add-ons' to increase utility and provide additional benefits of broader value than providing abundance indices.
7. Whether the FIS survey is useful as a stand-alone assessment.
8. Whether FIS surveys should be continued or discontinued.
    - If FIS surveys are continued, what changes or improvements should be made to improve their usefulness?
    - If FIS surveys are discontinued, what are the implications for assessments, and what are the alternatives for fishery independent surveys?

Required Outcomes

Provision of two Final Reports presenting the results of a critical review of the FIS surveys and recommendations regarding the future continuing, cessation, revision or improvements to the surveys to maximise utility of results. This report is the second of these two reports.

2 Reviewer's Report – Richard O'Driscoll

2.1 Professional background

As described in CTS report (O'Driscoll & Doonan 2015).

2.2 Overall comments

I did not have time to review all of the seven survey reports in detail. I focused on the 2015 report (Knuckey et al. 2015) that also summarised results of previous surveys, and I skimmed the earlier documents. My apologies if I have overlooked nuggets of information that were only described in early reports.

I found this series of surveys a lot easier to review than those in the CTS, mainly because of the use of a randomised stratified survey design (which I was familiar with), rather than a model-based design. I concluded that the design was appropriate for the target species, but not necessarily optimised and suggest that the number of sites could be reduced. I was gratified that there was a consistent vessel (Explorer S) and trawl gear (2015 issues not withstanding) over the time series and that parameters such as tow duration were constrained. The estimated CVs suggest that the survey series provided useful estimates for the target and associated species. My major concerns with survey series were as follows.

Comparison of station distribution maps (Figure 1 in various reports) suggest that the same sites were surveyed in each year. Is this correct? If so, reports need to be explicit that the design is a fixed site design, not a true randomised stratified survey design. There is considerable literature that deals with the advantages and disadvantages of alternative survey designs (e.g., review by Kimura & Somerton 2006). For example, a priori we might expect that with a fixed site design there will be less inter-annual variability between surveys, but that there is potential for bias (depending on whether the initial random site selection was "good" or "bad" by chance). As an aside, Figure 1 of Knuckey et al. (2015) seems to be truncated in the west?

The same sites seem to be surveyed day and night in each year, and Knuckey et al. (2015) note that "shots were carried out in a specified order to reduce temporal biases in the data collection". I would argue that by doing sites in the same order that you are potentially introducing temporal bias! For example, what appears to be a diurnal difference in catch rates of redfish may simply be because the (fixed) sites originally chosen as day tows were better redfish habitat than night sites! Even if the sites are fixed I think that you should be mixing up the time of day at which sites are fished.

The survey was stratified into four longitudinal strata, each covering the same depth band (120–200 m). The strata have remained unchanged since the start of the series (Knuckey et al. 2006) and it was unclear to me whether the strata are the most appropriate for the target species, and indeed whether there has been any re-evaluation of the choice of depth and longitude boundaries? I am grateful for the figure showing tow locations, but as for the CTS, I would also find maps showing spatial distribution of catch rates for key species (as expanding symbol plots) very informative as part of the annual survey reports. These would be useful to visually assess whether spatial distribution is stable over time and provide a quick assessment of whether strata divisions were appropriate. Certainly it appears redfish catches are consistently higher in central strata than in the west. As part of an exercise to determine optimal allocation of number of tows (see below), I would recommend re-evaluating strata boundaries.

The survey design and number of sites was originally based on CPUE (Knuckey et al. 2006) and has remained unchanged since the start of the series. As part of any discussion of survey "cost" I would urge re-evaluation of the number of sites required to achieve target CVs. For example, the target redfish CV of 20% has been achieved in all seven surveys with only about 38 night tows, while (using all 76 day and night tows) all surveys have come in with CVs of 5–7% for flathead - well below the target of 10%. I note that the target CV for flathead was achieved (9%) in 2015 based on only the 37 tows from Trip 2 and CVs for most associated species were still under 30% when the level of sampling was halved (Table 8 of Knuckey et al. 2015). This suggests to me that the level of sampling could be reduced without impacting the survey series. For (true random) trawl surveys in New Zealand, we use an optimal allocation programme (Francis 2006) to estimate number of sites required for key species based on previous catch rates. A similar exercise could be done for this series. Given a fixed budget, my "gut feeling" would be that more frequent surveys with fewer sites (therefore slightly higher CV) would be more informative for assessment and management, but this could be evaluated formally.

A clear constraint of the survey design and logistics is that only night time catches are used to estimate redfish, while day and night catches are combined for other species. This means (in effect) that there are half as many sites sampled for redfish than for other species. Is there any potential for reducing vessel costs associated with the survey by only doing night tows (e.g., by allowing the charter vessel to commercially fish during the day)?

There was an unfortunate issue relating to the change of net in 2015. This was resolved in two stages – minor tweaks after the first day of the first trip and then a more major overhaul between trips. The feeling I get from Knuckey et al. (2015) is that the authors are confident that the net used in Trip 2 of 2015 was comparable with earlier surveys, but that there is some concern over the configuration in Trip 1. Therefore I conclude that estimates based on only Trip 2 in 2015 are probably the "best" to use for assessment. However, the evidence for a difference in catch rates between trips 1 and 2 was not statistically compelling (see Tables 7 and 8 of Knuckey et al. 2015).

There was also a concern over the possible influence of nearby seismic survey during the first trip in 2015. Seismic surveys can impact catch rates, but without specific details of the type of seismic activity being carried out, the spatial and temporal overlap with the trawl survey (simply saying "within sight" isn't that informative), and some knowledge of the physiology of the species involved I am unable to comment on the likelihood of this having a major impact on results. It worries me that this might be a "red herring", or excuse, for what appears to be a major decline in abundance of the two target species. The only way to resolve this is to go out and do another survey. If I was managing this fishery I'd be strongly pushing for another survey in 2016.

In some instances, changes in survey catchability (process error) are observed as consistent changes in abundance across a range of species. To test for this, Francis et al (2001) proposed an extreme catchability rank test. This method ranks the survey years in order of increasing biomass index for each species and then compares mean rank across all species with expected mean rank. 'Extreme' catchability years are defined as those with probability less than 5% that the deviation of the mean rank from expected could be observed by chance if there was no between-species correlation. I applied this test to the 11 key species in the seven surveys (Figure 1), and found that (even if data from both trips were included), there was no evidence that catchability of the 2015 survey was significantly lower than other in the series.

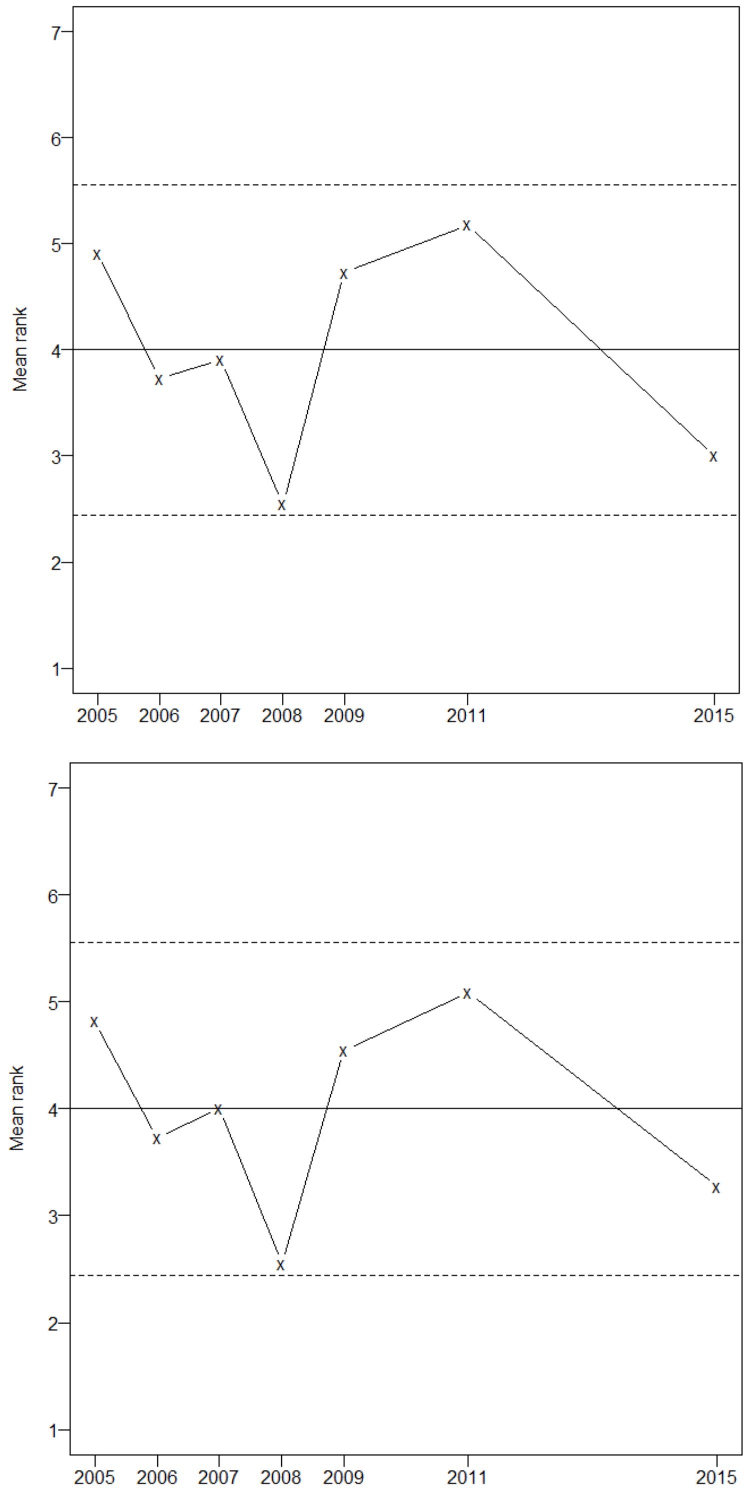

Figure 1: Francis extreme catchability test for key 11 species in GABT surveys 2005–15. 2015 data were based on all tows (Table 7 of Knuckey et al. 2015) in upper plot and data from trip 2 (Table 8 of Knuckey et al. 2015) in lower plot. Crosses show mean species rank of species in each survey year. Horizontal lines show expected mean rank with 95% confidence intervals if changes in species abundance are uncorrelated. Values falling outside these confidence intervals are considered to indicate ‘extreme catchability’.

2.3 Comments on specific Terms of Reference (ToR)

ToR 1: Were the FIS surveys are appropriately designed, for the given cost, to provide reliable abundance indices (with acceptable CVs) for the selected target species?

The average CV of the survey estimates for redfish was 15% and for flathead was 6%. Both were below the stated targets of 20% and 10% respectively. Abundance indices and length frequency distributions were also relatively consistent between years so appear to provide reliable indices. Recent declines in both species (and also jackass morwong) since 2009 are concerning.

As noted in my general comments above, it may be possible to reduce the number of sites (particularly for flathead) and still achieve acceptable CVs.

To evaluate variability in abundance indices between surveys I have found it useful to calculate CV from the annual estimates as though they are independent estimates of the mean of the same underlying population assuming this has not changed over time (I call this CV2) and compare this to the arithmetic average CV of the survey estimates (CV1). If CV2 is less than or equal to CV1 then the annual variability in abundance indices is within the variability expected purely due to sampling error (if the underlying population has not changed). If CV2 is greater than CV1 then either the variability due to process error is greater than the sampling variability (if the underlying population has not changed) or the underlying population has changed over time. As for the CTS surveys (O'Driscoll & Doonan 2015), I estimated the ratio CV2/CV1 for the GABT surveys (Table 1).

Table 1: Comparison of estimates of CVs from GABT surveys 2005–15 . CV1 is the arithmetic mean of survey CVs. CV2 is the CV estimated by treating survey abundance estimates as independent samples of the population. Data from Table 7 of Knuckey et al. (2015).

Species	CV1	CV2	CV2/CV1
Bight redfish	0.15	0.18	1.15
Deepwater flathead	0.06	0.10	1.78
Ocean jacket	0.23	0.28	1.22
Commion sawshark	0.18	0.20	1.07
Yellowspotted boarfish	0.20	0.16	0.80
Gummy shark	0.18	0.21	1.20
Jackass morwong	0.27	0.13	0.50
Knifejaw	0.14	0.10	0.74
Latchet	0.18	0.14	0.74
Ornate angelshark	0.09	0.08	0.86
Spikey dogfish	0.24	0.21	0.88

Based on this rough "rule of thumb" metric, most of the 11 main species appear to have levels of inter-survey variability (CV2) which were broadly consistent with the sampling CVs (CV1). For species where the ratio CV2/CV1 is much greater than 1, this appears to have been driven by recent declines (redfish, flathead, ocean jacket) or increase (gummy shark) in abundance (see Figures 18-19 of Knuckey et al. 2015).

ToR 2: The frequency within which surveys could be conducted (considering the impact of within year CVs and between year variations).

As I noted in my review of CTS surveys, the frequency of surveys should depend on: 1) expected time-scale of changes in abundance; and 2) the desired precision to detect change. In general, it is more important to have frequent surveys for fast growing short-lived species, where populations change rapidly in response to variable recruitment, than for long-lived species for which the expected rate of underlying population change is slower. To investigate this further, simple simulation experiments could be carried out of the type described by O'Driscoll & Doonan (2015).

I am concerned about the apparent decline of the two target species between 2011 and 2015 and suggest that it would be unwise to wait another 4 years before carrying out another survey. Indeed, in periods of rapid change it is desirable to have more (rather than fewer) surveys. Along with the concerns raised about gear performance in 2015, I would recommend doing another survey in 2016.

Given a fixed budget, my "gut feeling" would be that more frequent surveys (annual or biennial) with fewer sites (therefore slightly higher CV) may be more informative for assessment and management of these species, but this should be evaluated formally.

ToR 3: Where FIS data has been used, perhaps in addition to the main objectives, and what were the benefits? If not immediately beneficial, at what stage is it reasonable to expect that the FIS might become more valuable?

Average CVs less than 30% were achieved for all 9 other main species (i.e., excluding redfish and flathead) in Table 1, and average CVs less than 20% were achieved for 6 of these. These CVs suggest that the GABT series may provide useful abundance indices for all of these other species.

Because many other species are caught and measured, the GABT time-series may also provide an "ecosystem monitoring" role in the future (e.g., Tuck et al. 2009). For this reason, non-target species should continue to be quantified. Size-based metrics provide a broader range of ecosystem indicators than those based only on abundance (Tuck et al. 2009), so consistently measuring non-target species is also valuable (if time permits).

ToR 4: Whether the FIS surveys have provided acceptably reliable indices for the selected target species for use in Tier 1 assessments?

See my comments under ToR 1 above.

ToR 5: Whether alternative approaches (such as standardised CPUE indices, species-targeted surveys) offer acceptably reliable alternatives to FIS surveys for generating reliable abundance indices?

I did not evaluate this.

ToR 6: Whether FIS is effective at monitoring for target and bycatch and suggest improvements or 'add-ons' to increase utility and provide additional benefits of broader value than providing abundance indices.

As noted above, the GABT series potentially provides information on a wide range of species.

I did not consider the possible influence of survey timing in this review, but trawl surveys are unlikely to appropriate for species which are aggregated or migrating to spawn (O'Driscoll & Doonan 2015). If logistically possible it would be useful to record maturity observations (macroscopic gonad stages or gonad weight) on key species to help inform appropriateness of survey timing.

Recording echosounder (acoustic) data during trawling can help inform survey results based on aggregations of fish above the seabed. If the survey vessel has a suitable echosounder (e.g., Simrad ES60/ES70) then these data should be logged during the survey.

ToR 7: Whether the FIS survey is useful as a stand-alone assessment?

Repeating my comments on the CTS series (O'Driscoll & Doonan 2015), if GABT surveys can be demonstrated to track abundance with acceptable precision, then these may be useful for stand-alone assessment through some kind of decision-rule management strategy. The biggest obstacle is that survey indices are variable (due to sampling and process error) and this tends to lead to undesirable fluctuations in catch limits if these are linked directly. Assessment models tend to smooth out this variability and also allow predictions/projections and risk estimation (especially if the underlying models has other information on biological parameters and recruitment/age composition).

ToR 8: Whether FIS surveys should be continued or discontinued?

- *If FIS surveys are continued, what changes or improvements should be made to improve their usefulness?*
- *If FIS surveys are discontinued, what are the implications for assessments, and what are the alternatives for fishery independent surveys?*

In my judgement, these surveys are providing useful abundance indices for the two target species, and potentially associated species, and should continue. Consideration should be given to optimising the survey design to re-evaluate strata boundaries and potentially reduce the number of sites sampled. I am concerned about the confounding of day versus night fixed sites and suggest that in future the order of sites could be mixed up.

A clear constraint of the survey design and logistics is that only night time catches are used to estimate redfish, while day and night catches are combined for other species. It would be useful to compare night-only and day-only series for other species (particularly flathead) with those from all tows to see whether relative indices are consistent? If so, it might be possible to switch to a night-only design? I admit that this is counter-intuitive as many trawl surveys (including most NZ time series) have daytime only trawling as this is generally when demersal species occur closest to the bottom and catch rates are highest.

2.4 References

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3 Reviewer's Report – Ian Doonan

3.1 Professional background

As described in CTS report (O'Driscoll & Doonan 2015).

3.2 Overall comments

As with Richard O'Driscoll, I did not have time to review all of the seven survey reports in detail. I focused on the 2015, 2011, and 2006 reports (Knuckey et al. 2015, 2011, 2006).

The GABT has several good features for monitoring: randomised station positions, station allocation by strata and strata design based on CPUE data; covering the ground twice, once in each direction, to allow for migrations or movements, and, doing two trips because it allows the evaluation of consistency of the surveys. The resultant estimated CVs for the two target species, flathead and redfish, are very good, especially for flathead. The process error appears to be small or modest.

There are some non-standard features to this survey. The tow positions are for fixed sites which are trawled in every survey. Plotting the positions from 2011 and 2015 surveys show that they rarely coincide, i.e., they do not follow the exact same tow line, but they are within a local area that is small relative to the stratum area. Fixed sites means the variance for the random stratified survey design has potentially been reduced if there are strong local effects that persist in time and that the "bias" from the original position configuration is now fixed into the catchability. For redfish, this is a bit more complicated since they use only night tows which potentially means that different sites are occupied at night in each survey and there is a random component in the catchability from this effect. In theory, the formulae used to calculate the CV assume new random positions for each survey making the reported CVs an upper limit. Does this matter here? I do not think so because when I looked at the correlations of catches from the same site within the same stratum between 2011 and 2015 surveys, correlations varied from -35% to 22%, which are low. As a rule of thumb, correlations need to be over 70 to 80% to have a real impact of variances. The reported CVs are probably about right.

The binominal-gamma distribution is needed for situation where zeros are more than 10% (Schnute and Haigh, 2003). Here, this is not the case for flatheads and not needed for redfish in the C1 and C2 strata where most of its biomass resides. The gamma shape variable estimator (method of moments version) has a -1/n correction (n being the number of non-zero tows), which would be important for strata with low numbers of non-zero tows, e.g., trip1 for redfish in 2011 and 2015 has 2 or 3 non-zero tows in W1, and W2 in 2015 has 1 non-zero tow so these will have a high correction factor (Hwang & Huang, 2002). I also notice that some strata for redfish have very low sample sizes, especially in trip 1, e.g., 1 station in W2 (trip1, 2011), 2 stations in W2 (trip1, 2015). You cannot estimate CV in those situations, especially since the number of non-zero tows are even smaller. These strata (W1 & W2) contribute little to the overall redfish estimate so that they can be ignored, but it does affect the robustness of the analysis. For your target species, I do not think you get any benefit by using the binominal-gamma distribution over the usual equations.

3.3 Comments on specific Terms of Reference

ToR 1: Whether the FIS surveys are appropriately designed, for the given cost, to provide reliable abundance indices (with acceptable CVs) for the selected target species.

I think the survey is fit for purpose. The initial tow selection was random, which is a key feature for monitoring. The reported CVs are very good and process error appears to be modest, so the combined error is low enough to be considered reliable for fisheries work. The total CV (sample + process) for redfish may be just over the 20% mark (~22%), but I think that it would still be acceptable. I estimated the redfish process error from a period that was stable in the CPUE series, i.e., the first 5 surveys, and using the median cv over these same surveys. This gave a process error of 17%. Flathead had a low process error based on surveys 2006-9 and 2011 which covered a period that had a flatish trajectory in its stock assessment.

The design used fixed sites for trawling, but correlation at the same sites are low so I think that it can still be treated as random survey each year. I think that randomising each year may be better from a theoretical point of view, but fixed site surveys have their place, especially if finding fishable sites is time consuming.

The objective was for sampling CV to be below 20%. This is certainly achieved for both. Flatfish in particular has a median sampling CV of 5%, which is very good. At such a low CV, you could halve the number of tows and the sampling CV would increase by about 1.4 (√2) to 7% which is also very good.

Normally because of the fixed design, re-designing has been neutered so that improvements in the design cannot be made without affecting the catchability. Here, I do not think that this is a problem so data from the survey series can be used to adjust the design to get better performance since the original design was based on CPUE which is not the same as randomized survey data. I recommend that this be considered.

ToR 2: The frequency within which surveys could be conducted (considering the impact of within year CVs and between year variations).

This requires testing in a simulation environment with a set of events that must be detected within some specified time period, e.g., three years of poor recruitment. For example, if you expect only slow changes, then two or three yearly intervals (or longer) might be adequate, but then surprises will go undetected until the next survey and in my experience it takes two consistent results for it to be believed, which may lead to poor performance of the fishery. Wider spaced surveys would require a more dynamics approach to survey frequency so that unusual results are checked with a survey the following year.

ToR 3: Where FIS data has been used, perhaps in addition to the main objectives, and what were the benefits? If not immediately beneficial, at what stage is it reasonable to expect that the FIS might become more valuable?

Flathead survey biomass was incorporated into the stock assessment with CPUE, age and length data. The 2011 survey only just fitted to the model with the trajectory going through near to the upper confidence interval level. When FIS was dropped as a sensitivity, the current biomass as a percentage of virgin biomass changed from 45% to 54%, which makes it an important part to the assessment (on par with changing M by 0.04). The age and length data are very important to the assessment as judged by their log-likelihood contributions, so the assessment appears to be weighted towards those data. The 2015 survey abundance declined by a half from 2011 which is counter to the projected trajectory so there may be conflicts in the next assessment.

The GABT surveys are already valuable.

ToR 4: Whether the FIS surveys have provided acceptably reliable indices for the selected target species for use in Tier 1 assessments?

See my comments under ToR 1 above.

ToR 5: Whether alternative approaches (such as standardised CPUE indices, species-targeted surveys) offer acceptably reliable alternatives to FIS surveys for generating reliable abundance indices?

For the flathead stock assessment, CPUE has large error bars and so seems to have limited value compared with the age and length data. The error bars are so large that a horizontal line can pass through them all, as can an overall linear decrease or increase across the years that it spans (25% increase and 70% decline). This makes it a weak data source. Sections of the CPUE have correlated deviations from the estimated trajectory (i.e., long sections of model predictions all above or all below the CPUE). I think that the age and length data may be overwhelming the CPUE somewhat. When you consider the likelihood changes when datasets are dropped or down-weighted, the largest change occurs when re-weighting the age/length data and dropping GABT. Unless deliberately up-weighted, I do not think that CPUE on its own is sufficient.

I did not evaluate this for redfish since I could not find an assessment for it.

ToR 6: Whether FIS is effective at monitoring for target and bycatch and suggest improvements or 'add-ons' to increase utility and provide additional benefits of broader value than providing abundance indices?

See Richard O'Driscoll's comments.

ToR 7: Whether the FIS survey is useful as a stand-alone assessment?

For the target species, the FIS could be used for stand-alone assessment. But, you would first need to see more contrast in the abundance for them to be really useful. Currently, most indices are flatish (relative to CV), except for the 2015 index, which means that the only information on virgin abundance is for the lower bound which is based on the lowest virgin abundance that can support observed catch in the model.

ToR 8: Whether FIS surveys should be continued or discontinued?

- *If FIS surveys are continued, what changes or improvements should be made to improve their usefulness?*
- *If FIS surveys are discontinued, what are the implications for assessments, and what are the alternatives for fishery independent surveys?*

I believe that the survey should continue. If the survey is continued, then you could shorten both trips and revisit the station number allocation by stratum to improve performance. Note that errors enter as a square law so reducing the number of stations by a factor of 2 means that the CV increases by only ~1.4, so some saving can be made with only a little loss in precision. You could even re-stratify as long as the total area remains the same. Because it is a fixed site design, there are residual trends within strata that have been fixed into the catchability. However, this does not seem to be a big consideration since the correlation of catches at a site is low.

If you follow Richard O'Driscoll's suggestion of doing a night survey with commercial fishing during the day, then there will be a large saving in cost, but the resultant survey would retain the good index CV, especially for flathead. With approximately half the tow numbers, the flathead CV will increase to about 7%; the redfish CV remains the same. For redfish, the indicative total CV (sampling + process) is just over 20% (22%), but this may be lowered by a re-design or maybe it needs some extra stations.

You should consider sensors to measure important parts of the net performance, like bottom contact and net width. The latter can be affected by weather and speed variations and directly affect the biomass estimates. Also, some herding experiments will indicate whether wingtip or door spread is the more appropriate measure for the biomass calculation. Herding estimates, along with measuring escapement under the net, can provide an informed prior on the net efficiency part of catchability which will help fitting to the GABT in the stock assessment.

Discontinuing the GABT survey would potentially affect the flathead stock assessment in which the GABT survey seems to be important, for reasons outlined above.

3.4 References

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A review of research, monitoring and assessment approaches in North America, South Africa and New Zealand, focusing on cost effectiveness.

13 February 2016

Caveat regarding sources: This review is based on sources acquired online. In the preparatory stages a large amount of material was extracted directly from these sources. The majority of these extracts, but not all, were summarized. As such this document does not represent original work and original extract paragraphs may have survived. Attempts have been made to reference these sources and/or to include direct excerpts in quotes. Again these attempts are not perfect and there could well be surviving extracts that match those in the original sources.

1 Contents

2 Introduction

2.1 The costs of fisheries management

Fishery management costs comprise a substantial proportion of the revenue of landed fish (Costello et al, Arnason et al. 2000, OECD 2003, Wallis and Flaaten 2003). Citing Arnason et al (2000) and Wallis and Flaaten (2003), Costello et al (2015) note that management costs in Newfoundland, Iceland, and Norway range between 3 and 28% of landed value. For 26 OECD countries fishery management costs averaged 6% of the value of landings and varied between 0% and 70% (Wallis and Flaaten, 2003). In Thailand between 1991 and 1999, the range was from 0.7% to 1.64 % (Schrank et al. 2003), and in Namibia between 3.7% and 5.9% over the 1994-1999 period (Cunningham & Bostock, 2005). Management costs for countries such as Australia, Canada, New Zealand and the United States were, as a percentage of landed value (Arnason, 2000; Wallis and Flaaten, 2003):

1 Australia (Australian Commonwealth Fisheries only): 11%
2 Canada: 8%
3 New Zealand: 8%
4 United States: 18%.

It is of course important to put these %s into context in absolute terms, as provided in Table 8-1, an extract from Wallis and Flaaten (2003). This shows that expenditure in the USA on total fisheries services including research, management and enforcement costs is US$ 661 million, compared to only US$ 29 million in Australia. Research only in the USA dwarfs that in Australia by an order of magnitude, and the total value of fisheries in the USA is an order of magnitude greater or more than in Australia.

2.1.1 The scope of fisheries management costs: "fisheries services"

Wallis and Flaaten (2003) use the term "Fisheries services" to cover the spectrum of fisheries management activity comprising:

- "Research services": Research to inform fisheries management decisions

- "Management services": The creation and implementation of fisheries management systems
- "Enforcement services": The activity of enforcing fisheries management rules

This chapter is primarily concerned with the first two of these services, i.e. Research services and Management services, which would include all services leading up to the provision of scientific advice to management. That is, it would include but not be limited to:

- The costs of Fisheries Independent Surveys (FIS)
- At sea observer monitoring (ISMP)
- Stock assessments
- The development of harvesting strategies and management procedures.

These activities form part of a coordinated process which leads to the provision of management advice, as illustrated in the schema in Figure 8-1.

There is a danger of focusing just on the costs of providing fisheries services and neglecting benefits. A number of studies consider the trade-offs between costs, benefits and risks. Based on the results of simulation analysis and country by country reviews, Costello et al (2015) report that, although, as one would expect, the cost of fisheries services increases with the progression of fisheries management approaches across the spectrum: unregulated open access - to limited entry - to mortality managed input controls - to mortality management with output controls - to catch shares, the increase in benefits more than outweighs the additional costs.

Dennis et al (2015) present simulation results to assess the value of fisheries independent surveys for a specific example, a rock lobster fishery which straddles Australia and Papua New Guinea. Echoing Costello et al (2015), they conclude that the costs of fisheries independent surveys are more than compensated for by the benefits that are derived, viewed over a 20 year planning horizon. Punt et al (2002) confirm a similar result for fishery independent surveys in Australia's southern shark fishery.

Lallemand et al (2016) show that the MSC certification of the South African hake fishery is worth about 35% of the turnover value of the fishery, mainly as a result of the access to high value export markets that is achieved with certification. Here as well, although certification has led to a significant escalation in the cost of fisheries services in the fishery, most of which are costs borne by the industry, these costs are small in comparison to the benefits that have occurred.

Dowling et al (2013) attempts to quantify the risk-cost-benefit frontier in Australia's Commonwealth fisheries, focussing on the interaction between risk and cost. Although one might expect that risk and costs would be negatively correlated, this paper reports that risk is positively correlated with the costs of fisheries services. They propose that the reason for this is that fisheries that are perceived to be at risk attract research and other fisheries service costs. These data are therefore unable to provide clear guidance on how additional fisheries service expenditure may reduce risks, since the direction of cause and effect in the data is from risk to cost. Risk catch trade-offs cannot therefore be reliably used in conjunction with this study to relate expenditure on fisheries services to benefits such as higher levels of catch or CPUE. Ultimately Dowling et al (2013) suggested that an MSE approach is a better route to exploring such relationships.

It is of course a fact that, as pointed out by Costello et al (2015), the benefits that come from greater investment in fisheries services are mostly enjoyed by the fishing industry, and this naturally leads to the issue of cost recovery on a user pays principle.

Budget restrictions in Australia for the SESSF have impacted on monitoring and assessment work, and on the frequency of FIS, and at the same time there is growing public pressure in Australia for sustainably managed fisheries and for ecosystem-based management approaches. In Australia the combination of budget restrictions and greater expectations from fisheries management services has led to ad hoc decision making. This chapter forms part of, and informs, a larger initiative to structure a cost effective research, monitoring and assessment program for the SESSF for the next 5 years.

The following chapter is a review of recent development in North America, South Africa and New Zealand to provide insights into approaches which may assist with improving the cost-effectiveness of fisheries services, primarily research, monitoring and assessments. These headings group various fisheries service activities as follows:

Research

- Fisheries independent surveys
- Special projects
- Biological sampling

Monitoring

- At sea observer programmes
- Paper logbook systems
- Electronic logbook systems and electronic reporting
- Electronic monitoring in general including for e.g. VMS, AIS, video, camera

Assessments

- Stock assessments and the formulation of scientific advice based on these assessments

2.1.2 The relevance of a review of experience in North America, South Africa and New Zealand for practice in Australia

Adler and Pauly (2008) and Adler et al (2010) use 14 different indicators to rank 53 countries in terms of resource management efficacy, where the indicators used are grouped under the headings 'Biodiversity' 'Value' and 'Jobs', and pertain largely to the period 2000-2004, i.e.:

Biodiversity-related indicators:

1) Marine Protected Area Coverage
2) Investment to Marine Protected Areas
3) Change in EEZ Area Trawled
4) Seabird Protection Index
5) Marine Mammal Protection Index

Value-related indicators:

6) Landed Value Relative to GDP
7) The fishmeal consumption by Mariculture
8) Compliance with the FAO Code of Conduct for Fisheries
9) Context-Adjusted Fisheries Statistics Indicator, which measures the effectiveness of countries' fisheries reporting systems
10) 'Good' to 'Good + Bad' subsidies Ratio which measures financial resource allocated to management and surveillance relative to the sum of such 'good' subsidies and 'bad' (capacity enhancing) subsidies

Job-related indicators:

11) Catch Relative to Fuel Consumption
12) Subsides Relative to Landed Value
13) Socioeconomic Component of Mariculture Sustainability Index

Table 8-2 suggests that, except for Canada, the countries that form part of this review (i.e. New Zealand, the USA, South Africa and Canada) rank highly, and all except Canada rank above Australia, confirming the value of examining more closely how these countries deliver fisheries services for effective marine resource management.

3 USA

3.1 Overview

The USA has the largest EEZ in the world and its fisheries are diverse. The National Marine Fisheries Service (NMFS) is a United States federal agency, informally known as NOAA Fisheries, responsible for the stewardship and management of the nation's living marine resources and their habitat within the EEZ. Under the Marine Mammal Protection Act and the Endangered Species Act, NMFS is also responsible for the recovery of protected marine species such as wild salmon, whales and sea turtles. NMFS is a division of the National Oceanic and Atmospheric Administration (NOAA) which falls within the cabinet-level Department of Commerce. NOAA oversees the NMFS. NMFS manages marine fisheries with the help of six regional science centers, eight regional fisheries management councils, the coastal states and territories, and three interstate fisheries management commissions. While the coastal states and territories generally have authority to manage fisheries within near-shore state waters, the NMFS has the primary responsibility to conserve and manage marine fisheries in the U.S. exclusive economic zone beyond state waters.

The six regional science centers are:

- The Northeast Fisheries Science Center headquartered in Woods Hole, Massachusetts.
- The Northwest and Alaska Fisheries Science Centers are both located in Seattle. The Alaska fisheries Science Center is located on the grounds of the now-closed Naval Station Puget Sound. The Northwest Fisheries Science Center is located adjacent to the University of Washington.
- The Pacific Islands Fisheries Science Center is headquartered in Honolulu, Hawaii, on the campus of the University of Hawaii at Monoa.
- The Southeast Fisheries Science Center is headquartered in Miami, Florida
- The Southwest Fisheries Science Center is headquartered in La Jolla, California

The eight regional fisheries management councils are:

- North Pacific Fishery Management Council (Alaska)
- Pacific Fishery Management Council (West Coast)
- Western Pacific Regional Fishery Management Council (Hawaii and Pacific territories)
- Gulf of Mexico Fishery Management Council
- Caribbean Fishery Management Council (Puerto Rico and U.S. Virgin Islands)
- South Atlantic Fishery Management Council
- Mid-Atlantic Fishery Management Council (Upper North Carolina to New York)
- New England Fishery Management Council

Before getting into the details about approach to fisheries management in the USA is is relevant to note that in 2002 expenditure on fisheries services in the USA including research, management and enforcement has reached US$ 661 million, compared to only US$ 29 million in Australia.

3.1.1 USA: Research: Fisheries Independent Surveys

NOAA (1998) is a description of a data acquisition plan to outline how NOAA Fisheries' data requirements will be met over the next five years. Changes on the horizon, such as management philosophies and impending technological advances, which will influence the way resources are researched, monitored and managed in the future are evaluated. The plan in NOAA (1998) focusses on the acquisition of fisheries-independent data and evaluates the available research platforms, including NOAA or other fisheries research vessels (FRVs), chartered fishing vessels and university ships. NOAA (1998) reports that a multidisciplinary team from government agencies, academic institutions and private industry concluded that a new generation of FRVs was needed, and discusses the construction of a core fleet of purpose-built, dedicated FRVs, and their integration with chartered vessels from the academic and private industry fleets. NOAA (1998) notes that about 40% of requisite ships time is provided by non-FRVs.

Amongst other requirements for FRV design, NOAA (1998) discusses the need for acoustic quieting of FRVs to reduce behavioral responses by species targeted in surveys and to minimize noise interference with hydro-acoustic signals. It notes that FRVs must have

- The necessary speed, power and endurance to allow acoustic and trawl surveys at the shelf edge
- Adequate berthing to support a full scientific complement
- Be configured to support laboratories, computers and multi-gear (e.g., trawl, longline, oceanographic) capabilities.
- Be available for fisheries missions for at least a decade to protect the integrity of long-term resource surveys.
- Be able to accommodate technology development and mission changes over their service lives.

In order to make recommendations for FRV requirements NOAA carried out a detailed assessment of the precision of all surveys carried out under the auspices of NOAA and studied the precision trade-offs of either increasing or decreasing the amount of survey time. Figure 8-2 illustrates the typical trade-offs that were revealed from this analysis.

The analysis concluded that 9.3 ship years of FRV time, supplemented with non-FRV (e.g. fishing vessel, research vessel) charters, are needed to meet at-sea data requirements per calendar year. The plan calls for four new purpose-built FRVs to be constructed, deployed and calibrated for service. Since these will only at best be able to supply 4 ship years of time compared to the required 9.3 ship years, NOAA will continue to rely on vessel charters to make up the shortfall. We quote from NOAA (1998):

"Fisheries has steadily increased the use of vessel charters to the point that they represent about 40% of the total DAS in FY98 (days at sea in fishing year 1998). Use of charters will continue to increase in response to burgeoning information requirements and to the retirement of vessels in the NOAA fleet. Perhaps the factors that limit the use of charters most are the types of vessels available for charter and consistency in availability. Some missions simply must be conducted from an FRV with long-term availability. NOAA Fisheries will continue to work closely with the academic and fishing industry fleets to use them for suitable missions. In addition to that, FRVs that can be used to supplement the work of NOAA's core fleet of vessels are needed. UNOLS currently does not have fully capable FRVs in their fleet. However, plans are underway to modernize the academic fleet and this represents an opportunity to collaborate with them to meet NOAA Fisheries' vessel needs. UNOLS and NOAA Fisheries representatives have a healthy working relationship and collaboration is being actively pursued."

We note further, amplifying the above, that NOAA (1998) reports that the commercial fishing fleet is a valuable resource to NOAA, and contributes significantly to the pool of data used to manage fisheries. Many missions are ideally suited for fishing vessels, such as gear test studies, bycatch studies, and exploratory fishing. Chartered fishing vessels are also appropriate platforms for standardized stock abundance surveys that use gears less sensitive to changes in vessels, such as traps, purse seines, and longlines. Vans containing specialized acoustic or laboratory equipment or dormitory space can sometimes be placed aboard these vessels to temporarily enhance their capabilities. Challenges to the use of commercial fishing vessels include availability of suitable vessels, and continuity of availability. Standardized sampling often requires a relatively rigid sampling schedule to maintain data continuity. When a sampling season coincides with a commercial fishing season, the few charter vessels willing to shift their focus from fishing to data collection will do so only at a prohibitive cost

The new FRVs are designed to accommodate three new technologies that improve the precision of fisheries assessments and enhance process-oriented research:

- Research hydro-acoustics: Already in use for estimating semi-pelagic fish stocks, this technology continues to develop rapidly. Improvements in transducers and signal processing combined with use of multiple frequencies are leading toward higher target resolution and discrimination
- Video: Continuous developments in towed camera arrays will improve real-time assessments of benthic epifauna.
- ROVs and AOVs (Remote- and Autonomous-Operated Vehicles): These vehicles, equipped with low light level cameras, can augment and extend population assessments to areas where sampling is not possible by traditional techniques (reefs, rock areas).

The FRVs must include a number of special capabilities in their design, including

- Acoustic quieting to meet the Council for the Exploration of the Seas (ICES) standards for hydroacoustic surveys. This is the most important special requirement of new FRVs. Acoustically quiet vessels will reduce the noise at frequencies known to disturb surveyed fish (less than about 1 kHz), thereby increasing echo detection and reducing avoidance reactions of fish or marine mammals. To reduce noise at the higher frequencies used to assess fish (usually 38 and 120 kHz), extendible transducers, e.g., mounted on a centerboard, should be used.
- Versatility of deck equipment, deck space, laboratory space, to study the relationships among managed species, the food web, and the environment upon which they depend in near real-time.
- Modern science laboratories and scientific equipment. In addition to processing (wet) laboratories, the new vessels require laboratories with stable electrical power for supporting sensitive analytical instrumentation.
- A modern computer system for integrating meteorological, oceanographic, and hydro-acoustic, and positional data acquired through ship's sensors.
- Sea-kindliness (a smooth and stable ride) is essential for investigators working in on-board laboratories. Violent motions can degrade and even preclude operation of many scientific instruments.
- Station-keeping through thrusters, integrated with a dynamic (computer-controlled) positioning system, to remain on-station for prolonged sampling periods and to follow precise track lines in a variety of sea conditions are needed.
- Adequate number of berths for scientific complement. *In situ* and laboratory experimentation require a diverse team of scientists and support technicians. Depending on the program, the scientific complement will require up to 19 staff.

3.2 USA: Electronic Tracking, Monitoring and Reporting technologies

A number of electronic (e) technologies exist, with three broad groups being the standard for fisheries data collection:

a) Vessel Tracking (T),
b) Camera Monitoring (EM),
c) Electronic Reporting (ER).

There is increasing interest in these technologies in the USA because they offer the potential to improve the quality of data collected for compliance, science and management, and reduce data collection costs. The status of these technologies is that they are ever evolving, are in various states of implementation in various regions of the USA, and in many cases they are being tested and their implementation has not been made mandatory.

3.2.1 *Vessel Tracking*

Vessel tracking data includes a vessel's identification, location, bearing, speed, and a time-date stamp. Tracking information can be collected in various ways. Four significant examples are

- VMS: vessel monitoring systems
- AIS: automatic identification systems
- SAR: synthetic aperture radar
- eLog: electronic logbook systems.

VMS: Vessel Monitoring Systems (VMS) are currently the most common technology used for real time tracking of fishing vessels. A typical VMS unit tracks and stores a vessel's unique ID, position, speed and bearing and transmits this information to a shore in pre-agreed intervals, typically every two hours but sometime as little as once or twice a day, and in other cases as often as every 15 minutes.

Automatic Identification System (AIS): Automatic Identification Systems (AIS) have been implemented in various areas for vessel tracking purposes. An AIS transponder is used to convert vessel ID and tracking data into VFH radio signals, which carry these data to nearby AIS receivers, installed on vessels or on shore. Because of reduced transmission costs they are cheaper to run than VMS.

Synthetic Aperture Radar (SAR): SAR is based on software that processes images taken by SAR satellites, in order to locate recognizable patterns or characteristics in the image, which typically represent the presence of a vessel at sea. Unlike VMS and AIS, processing SAR images is not intended to identify particular vessels, but rather to simply detect where vessels are present (or not). However new technologies are now capable of linking SAR images to a vessel's specific AIS and, if available, its VMS records.

Electronic Logbook: Vessels can also be tracked by linking the vessel GPS to electronic logbook (eLog) software, and then sending vessel location and other related information to the shore on a regular basis with any eLog report that is sent.

3.2.2 *Camera Monitoring*

The goal of camera monitoring is to provide a cost-effective monitoring solution capable of collecting data for scientific, management, and compliance purposes. Surveillance cameras installed on vessels have proven to be effective at recording crew and fishing activities, which can be checked for compliance with fisheries regulations (WWF, 2014a, p. 32). Camera monitoring that is integrated with eLog can provide a means of validating vessel catch and gear reporting, strengthening traceability.

There is still an open question about whether, when and how camera technology could replace human observers at sea, and this question is being tested via a range of pilot studies ongoing in the USA.

3.2.3 *Electronic Reporting (ER) and Electronic Logbooks (eLog)*

The term electronic data reporting (ER) generally refers to a digital version of a paper-based reporting process. ER for fisheries data collection requires the deployment of a software program specifically developed for fishing data collection. Such software is referred to as an electronic Logbook or eLog. In fisheries, electronic reporting is used to record and report vessel activities, catch, the fishing gear(s) used, landing reports, trans-shipment reports, boarding inspections, in-port inspections, and departure and arrival reports (hails). In addition, ER solutions can be developed to integrate new variables and data sources such as environmental and biological data typically not required by management and compliance authorities. A further advantage of this technology is that it can and has in certain products been extended beyond a simple electronic logbook to become a vessel or fleet specific data centre in which all data submitted to the fisheries authorities is stored together with a great deal of other data for use in ship and fleet level management by the commercial operator.

3.2.4 USA experience with EM Monitoring and ER

A number of studies have been carried out in the USA to assess the ability of EM technology to replace human observers for compliance purposes and for gathering data for management and science. These studies have made exclusive use of video technology as the foundation technology for EM, since this was the only EM technology available at the time. More recently high definition camera technology, and integrated ER/EM technology, has become available. Testing of this technology in the USA is pending. Ames et al (2005) reported the successful application of video technology for monitoring the deployment streamers and for seabird identification on longline vessels, and noted that for these vessels EM costs that were in the order of 40 - 50% of the regular human based observers are achievable. The typical EM system consisted of automated processing devices with data loggers linked to digital video cameras, a hydraulic transducer, and a global positioning system. Ames (2005) reports that there are observation discrepancies between EM and at sea human observers and make suggestions for reducing these discrepancies. Bonney et al (2009) reports that EM technology can provide data for the management of RPP halibut prohibited species quota at a price comparable to at sea observers, and notes that **reliability issues experienced during the project can be resolved.** Bonney et al also notes that programs designed to automatically identify fish by species using EM have not been developed sufficiently for actual use, the measurement of halibut size by passing them across a marked grid is a probable solution for measuring fish and accumulating size structure data. Cahalan et al (2010) compared estimates of bycatch from fishery observer documentation with estimates based on EM, and found that lapses in EM data capture during trips occurred which encompassed large portions of, or entire, fishing trips. Cahalan et al (2010) notes that EM, **although limited in scope**, can provide an additional tool for catch monitoring in the commercial halibut fishery, and that EM is not an alternative to observers for the collection of certain biological data and specimens (e.g., otoliths, scales, etc.). With the further development of EM systems and procedures, estimation of bycatch species composition in numbers of fish in the Pacific halibut fishery could be achieved with a high degree of accuracy.

NOAA and NEFSC (2015) found that in the specific case of the midwater trawl herring/mackerel fishery EM is substantially less expensive than human observers, **in large part, because for this fishery the video only needs to be viewed for identifying discard events**. It also found that **after the initial EM implementation costs, the hypothetical EM program would cost about one-third as much as the at-sea observer program annually.**

Despite the above assessment of the potential for EM technology in the USA, NEFSC 2010 (drawing from the covering letter to the final report by the NMFS) stated that **at this point EM is also not sufficiently effective at monitoring weights of discarded fish by species**, and that a multiyear pilot project will continue to work to address these system deficiencies so that EM technology can be considered for use, in lieu of traditional at-sea monitors.

NOAA (2013) notes that d**espite numerous past and ongoing video monitoring pilot projects there are currently no operational video monitoring programs in NMFS-managed fisheries where data extracted from video are used for science or management purposes.** This is due to operational issues including the ability to accurately identify species, ability to estimate weights of discarded fish, and length of time required to obtain and review video and extract all requisite information. NOAA (2013) does point out however that ER is generally considered effective at capturing fishery dependent data, and to date video monitoring has proven to be most effective as a compliance tool. Video monitoring may not be effective for identifying protected or prohibited species. Video monitoring projects vary widely depending on the management objectives of the monitoring program, and may not be more cost-effective that observers.

NMFS Alaska (2015) presents an implementation plan for electronic technologies in the northern Pacific region which addresses both electronic monitoring (EM) and electronic reporting (ER) and highlights the use of EM for compliance monitoring, reporting success with EM for compliance monitoring for all catcher/processors and motherships that use flow scales, the AFA pollock catcher/processors, the Rockfish and Amendment 80 Programs, and the Pacific cod freezer longline fishery in the Bering Sea.

Significantly NMFS Alaska (2015) emphasizes that EM data can be reviewed when other information suggests the need for review, through random audit checks, or anytime to verify that the EM system is functioning as required. For example to require industry to self-report, and then to use EM to audit, or verify compliance reporting requirements. The Canadian hook-and-line groundfish is an example of such an approach. The review effort required to verify compliance can thus comprise only portions of the information that is recorded, as suggested in Stanley et al (2011).

NMFS Alaska (2015) also points out the potential for using EM / ER technology for data collection for management and science, and provides Table 8-3, a list of fisheries that are judged to be suitable for the implementation of EM/ER. NMFS Alaska (2015) also summarises the different regulatory approaches that have been used to implement EM / ER programs in Alaska, and outlines the status of a number of EM / ER initiatives in the state.

Loefflad et al (2014) outlines a "Strategic Plan for Electronic Monitoring and Electronic Reporting in the North Pacific" and also presents Table 8-4, a summary of existing monitoring tools currently implemented in the North Pacific fisheries.

NMFS Alaska (2015) summarises the "EM/ER Strategic Plan for the North Pacific" presented by Loefflad et al (2014). The key points of this strategic plan are a series of goals, objectives, strategies and actions to pursue the following vision:

"A future where electronic monitoring and reporting technologies are integrated into NMFS North Pacific fisheries dependent data collection program where applicable to ensure that scientists, managers, policy makers, and industry are informed with fishery dependent information that is relevant to policy priorities, of high quality, available when needed, and obtained in a cost effective manner."

NEFSC (2015) is a set of Electronic Monitoring System Specifications.

SEFSC (2015) sets out a regional implementation plan for electronic monitoring and reporting. This document notes that in the southeast region, over the past 15 years, numerous pilot studies have been completed examining the use of EM and ER in federally managed fisheries. These activities have included the implementation of electronic reporting systems in a variety of fisheries for a variety of purposes, including those summarized in Table 8-5 and Table 8-6.

There have been a number of EM pilot studies in the southeast region but no stipulation yet for their use in the region (see Table 1 of SEFSC, 2015). SEFSC (2015) states that their focus is on expanding the use of ER to improve the timeliness and quality of data for use by managers and scientists - they foresee greater benefits from the expansion of the use of ER. Although they view EM as important for improving science and management, the actual development and implementation of EM, especially the use of video camera systems, is considered a longer term implementation goal than ER, although they recognize the potential of this technology for habitat protection, bycatch/catch estimation, and the enforcement of fishery regulations.

SEFSC (2015) also notes the mandatory use of VMS on Gulf reef fish vessels, South Atlantic rock shrimp vessels, and various highly migratory species (HMS) vessels. VMS is used by federal fishery managers and law enforcement to monitor fishing activity and enforce spatial-area closures and gear-restricted areas. They are also used by the Coast Guard to locate vessels in the event of emergencies. AIS is presently mandated for use by vessels more than 65 feet in length. SEFSC notes that AIS may be a cost effective alternative to VMS that could be used in the future to monitor fishing activity in the southeast region. SEFSC (2015) goes into more detail about the different opportunities or the expansion of the use of ER / EM, and maps out a plan up to 2017 for pilot testing and adoptions where relevant.

SEFSC (2015) notes significantly that in evaluating costs, NMFS should consider establishing data standards and auditing data, rather than serving as a software developer. This would allow for cost savings by reducing upfront costs for development, maintenance, and upgrades. NMFS, or other partners, would then accept data, validate it as it comes in, and store the data for use.

The foregoing section is based almost exclusively on the use of video technology as the base technology for capturing data as part of EM. It needs to be appreciated that many other technologies are either available or under development.

3.2.5 Camera still based EM technology

Another type of technology emerging as an alternative to the EM/Video technology involves an integrated ER/EM approach using high definition camera stills rather than video technology, and uses the ER as the driving technology. Images are fully integrated into the ER database technology tying images unequivocally to data. The use of this technology needs to be evaluated in the field to assess its capabilities on a number of criteria including

- Monitoring capabilities in general
- Image quality. To what extent does this technology improve the achievement of monitoring objective.
- Robust. Hardware robustness and durability.
- Ease and cost of installation. These costs can be considerable.
- Reduced maintenance cost
- Efficiency. The efficiency of reviewing images.
- IT Hardware required for review work.
- Data recording volumes and storage costs for high quality imaging
- Flexibility.
- Power consumption.
- Image backup andsecurity systems
- Other technological advantages (e.g. Backup batteries, Embedded GPS, Internal satellite transceiver are three claimed by producers)

These systems are only entering the marketplace now and need to be assessed in the field.

3.2.6 USA: Prioritizing Fish Stock Assessment

In the USA the Magnuson-Stevens Act (MSA) is the backdrop against which the planning and deployment of fisheries services takes place. The MSA requires that fisheries management be based on the best available scientific information. Given that fisheries service resources are limited, there is a need to prioritize the deployment of stock assessment resources. The initial reference point for reviewing NOAA's response is a paper by Mace et al (2001), which categorizes assessments according to five SAIP (Stock Assessment Improvement Plan) levels:

1. Assessment based on empirical trends in relative stock abundance;
2. Assessment based on a snapshot equilibrium calculation;
3. Assessment based on time series of catch and an abundance index to support application of a dynamic model;
4. Assessment is age-structured, so needs time series of age and/or size data and can now estimate changes in fishery characteristics over time and can estimate fluctuations in annual

recruitment, and has direct information on the fishing mortality of each year class entering the stock;

5. These assessments link to ecosystem, habitat or climate factors to help explain and forecast the fluctuations that are empirically measured in a level 3 or 4 assessment.

(Assessments at level 3 are generally considered to be able to determine overfishing and overfished status, but are marginal for the purpose of forecasting changes in annual catch limits. Most assessments are conducted at level 4 today and a few have achieved a level 5 status. Several different modeling approaches are used, but there has been evolution towards models that are internally age-structured but very flexible in data requirements.)

NOAA (2014) is a Draft Protocol for Prioritizing Fish Stock Assessments which makes use of these SAIP levels and a range of other inputs, indicators and proposed procedures. Methot (2015) is a similar document which covers the same ground.

NMFS Science Centers have recognized the need for prioritization and streamlining of the assessment process. Other nations have also recognized this need. For example in 2011, ICES conducted annual assessment updates for 144 stocks and biannual assessments for 48 stocks, and reached the following conclusion with regard to reducing assessment frequency and deriving multi-year management advice from some assessments:

"WKFREQ suggests that multiannual management approaches can only be considered for a limited subset of ICES stocks, namely those with robust assessments and modest exploitation, those with a limited amount of new information each year, those with very noisy data, those in which management is only weakly directed by assessments, and those in which individuals are very long lived and exploitation is (again) modest. Stocks in any other circumstances are unlikely to be suitable for a multiannual approach.

Even in suitable cases, the risk of changing to a multiannual system needs to be evaluated using a quantitative approach such as an Management Strategy Evaluation. Such an evaluation needs to consider the assessment model used and its uncertainty, survey and recruitment variability, the initial state and trajectory of the stock, the management approach used, how well the fishery performs economically, and more qualitative aspects such as political sensitivity. An evaluation that ignores one or more of these aspects in determining suitability may well reach the wrong conclusion, with potentially damaging consequences."

In the US potentially over 1000 stocks require assessments. However, in 2013, there were 478 managed stocks and stock complexes in fisheries management plans. Given the impracticability of achieving this on an annual basis, in 2005, the Fish Stock Sustainability Index (FSSI) was created and the 230 stocks included in this index effectively became "core" stocks. FSSI stocks contribute 90% of the catch, although some stocks are on this list because of a history of overfishing or other reasons which increase their importance for assessment work. The breakdown of these stocks and stock complexes by management council is shown in the table below, i.e. they are unequally distributed amongst jurisdictions. There are 46 FMPs in total and each contain between 1 to many tens of managed stocks.

Table 1. This table presents the distribution of FSSI and non-FSSI stocks among Councils and Science Centers in 2014. Each row in this table represents a category within which prioritization could occur, with exceptions in the note below.

Council	Centers	Non-FSSI	FSSI	All
CFMC	SE	37	8	45
Atl_HMS	SE	6	21	27
GMFMC	SE	15	23	38
SAFMC	SE	21	22	43
NEFMC	NE	2	37	39
MAFMC	NE	0	11	11
NPFMC	AK	30	35	65
PFMC	NW-SW	17	45	62
PFMC_salmon	NW-SW	67	0	67
Pac_HMS	SW-PI	14	18	32
WPFMC	PI	42	7	49
		251	227	478

Note: HMS refers to Highly Migratory Species. Stocks that are shared between the GMFMC and SAFMC would be covered by the GMFMC unless otherwise arranged by the SEDAR (Southeast Data and Assessment Review) committee. The MAFMC and NEFMC could be covered by the same prioritization process, as occurs now with the Northeast Regional Coordinating Committee.

The proposed schedule for application of the prioritization process would have each Center take a tiered approach with their respective Regional Council or other partners to cover all stocks in their jurisdiction:

- The first tier would cover the domestically assessed and managed FSSI stocks.
- The second tier would extend to other managed stocks, species within managed stock complexes, ecosystem component stocks, non-FMP internationally managed stocks, and state/commissioned managed stocks as appropriate for the particular Center.

<u>NOAA (2014) recommend a regional application of the stock assessment prioritization process, and not a fully national level application.</u> The stock assessment prioritisation process recommended by NOAA (2014) can be divided into two, the first is a determination of the SAIP level of assessment appropriate for a stock and the appropriate assessment frequency, the second is a prioritization step per governing the distribution of stock assessment resources amongst stocks. This second process is dynamically updated as circumstances change over time. In some more detail, the two processes are:

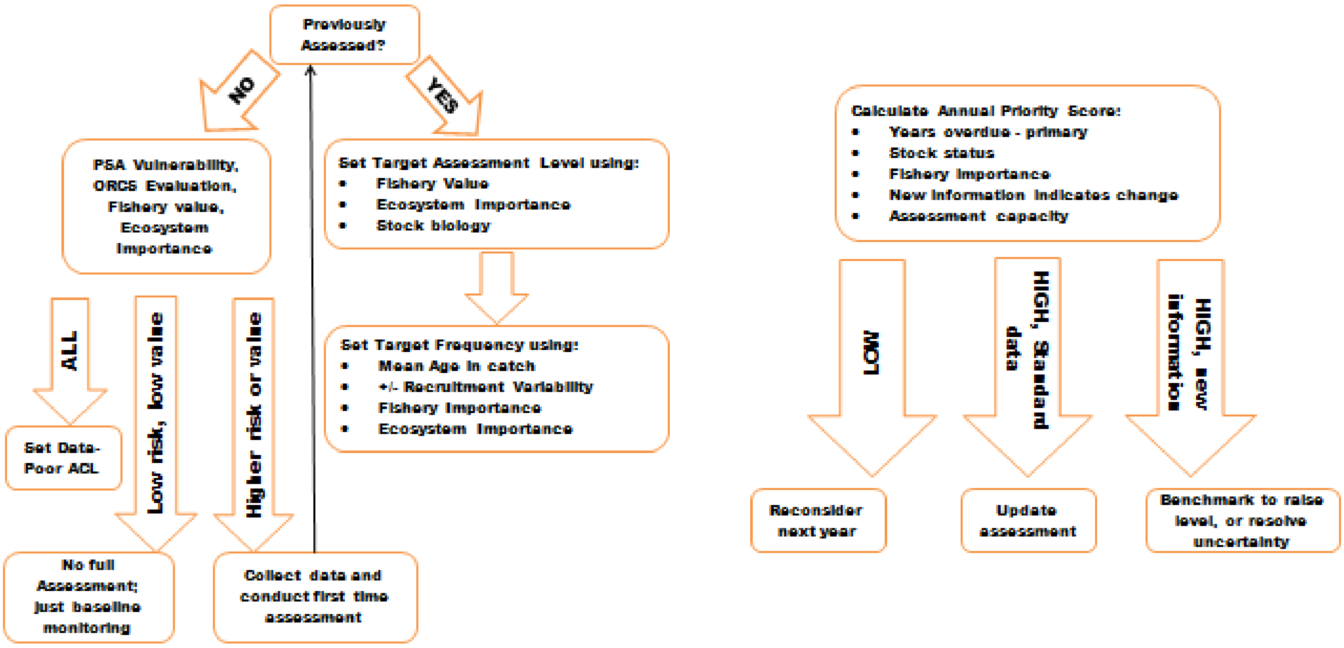
1. Target Assessment Level and Frequency:

- Among unassessed and previously assessed stocks, set medium-term assessment goals
- Among stocks that never have been assessed, set priority for first-time assessment, if any, or conclude that current level of baseline monitoring is sufficient.
- For stocks that need assessment, set target assessment level; this drives the data requirements
- Set target assessment update frequency for each stock

2. Prioritize to Achieve Targets: Annually update priorities for conducting assessments, with a portfolio approach to allocate assessment capacity to achieve a mix of first-time, benchmark, and update assessments:

- Benchmark assessments for assessments needing improvement or for which new data will allow advancing to higher level;
- Update assessments for stocks that are at or exceed their target update period.

The following flow charts summarize these two processes, with the setting of the target assessment level and frequency on the LHS, and the process of prioritization to achieve targets summarized on the RHS (source NOAA, 2014):



The process on the LHS of the above figure is an initial step that is updated occasionally, but not annually. The process on the RHS is an annual process to establish priorities for conducting assessments to achieve the goals of comprehensiveness and timeliness. The process on the LHS of the above figure refers to PSA Vulnerability and ORCS evaluation criteria for the assessment of targets and priorities. Previously unassessed stocks need a quick examination to determine which of these can stay at an unassessed level, which can be adequately tracked with simple baseline monitoring, and which need a first time assessment. Two recently developed tools recommended by NOAA (2014) assist with this task:

1. The Productivity-Susceptibility Analysis (PSA) (Patrick et al., 2010) produces a score that ranks stocks according to their vulnerability to being overfished, and hence in need of assessment.
2. ORCS, a data-poor approach (Only Reliable Catch – ORCS) (Berkson et al., 2011) is a tool that looks at available information regarding catch, other species in the fishery, and simple indicators of trends in stock abundance. It evaluates whether recent exploitation rate is light, moderate, or heavy; then provides advice on an Annual Catch Limit that should prevent overfishing until a more complete assessment can be completed.

Table 8-7 from Berson et al (2011) documents the attributes that are considered in the ORCS schema to assign a stock status of lightly exploited, moderately exploited or heavily exploited, but does not go into detail about the allocation of catches.

The priority for the first-time assessment of stocks can then be based on the PSA's biological vulnerability to overfishing, the ORCS' information on fishery impact level (stock status), and fishery and ecosystem importance. PSA scores range from 1.0 for the lowest vulnerability to 3.0 for the highest vulnerability. The ORCS score for exploitation status also ranges up to a maximum value of 3.0. These two scores are added to a fishery importance score and an ecosystem importance score to obtain an overall score. Where data implement PSA and ORCS are lacking, expert judgment is required. The result will be a set of scores within a region to rank stocks according to their need for a first time assessment. Some of these will show a high need, but sufficient data to conduct the assessment may be lacking. Others may have sufficient data for an assessment, usually because data has been collected by a multi-species sampling program that provides data on all encountered species. Some species will score low on this scale, so have low priority for immediate assessment. They should not be ignored. Baseline monitoring to the extent feasible should continue and PSA and ORCS should be updated on a 5-10 year basis.

For stocks that have been previously assessed it is necessary to determine the target assessment level and frequency. The following factors are considered for this:

1. Fishery important - i.e. commercial and recreational value to the regional fishing communities
2. Ecosystem importance - role of the stock in the ecosystem and strength of its interactions with other species
3. Stock status - relative to target and limit levels of abundance and fishing mortality
4. Stock biology - how much change is expected per year, on average
5. History of assessment - including availability of new information to resolve extant issues or indicate a change in stock abundance.

An explicitly numerical approach is then implemented (see NOAA, 2014) to derive an **aggregate importance score** to guide decision making on the assessment level, frequency, and annual priorities for assessments, as is now described briefly:

NOAA (2014): "After a stock has been assessed once, there should be enough information available to evaluate medium term goals for future assessments. Ideally the goal would be stated in terms of a desired degree of statistical confidence in assessment results. While many assessments present results with confidence intervals, the methods are too diverse to support direct comparison and all are not yet able to incorporate the effect of changing ecosystem factors on uncertainty in assessment results.

Consequently, a simpler approach is to establish a target for the comprehensiveness (level) of each assessment, and a target frequency for updating the assessment.

Level and frequency are considered separately because the types of resources needed to accomplish them are quite different. Increasing the level of an assessment generally requires acquiring a new kind of information. For example, going to an age-based assessment requires routine collection of data on fish ages. Addition of fishery-independent survey is another type of investment that can improve assessments. Increasing the frequency of assessments does not require new kinds of data, but does require addressing bottlenecks that impede conducting more assessments each year. For example, these bottlenecks could be more age readers to process existing age samples more quickly, more scientists to simultaneously work on more assessment updates, and/or better assessment standardization to streamline the assessment review process."

Target assessment level: NOAA (2014) seems unable to prescribe the target assessment level appropriate for a given stock and refers back to Mace et al (2011) noting that further revisions of the SAIPs are underway to provide a more reliable description of the present state of an assessment - then a prioritization process will be implemented (one assumes using the aggregate importance score) to provide advice as to whether the current SAIP level for a stock is appropriate or whether improvements are required.

Target assessment frequency: A pragmatic starting point is to use the mean age of fish in the catch as the target interval between assessments. Alternatively, one could use a formula based on total mortality (Z) or natural mortality (M). If all fish are recruited at age 1, then mean age in the catch is closely approximated by 0.5+(1/Z), or by 0.5+(1/(2*M)). It may be necessary to multiply this mean age by a scaling factor to achieve a good overall level of assessment frequency, and to average mean age data over several years to remove the effect of variable recruitment. The value of this scaling factor will be set after enough of the data elements are collected to do a preliminary application of the target setting process. Then decrease this interval by a specific amount for stocks with high levels of recruitment variability, or increase by a specified amount for stocks with low variability. A nonlinear scale or a cap may be needed so that very long-lived stocks are not assigned an unreasonably long assessment interval. Evaluation and refinement of this approach and consideration of additional biological factors must wait for collation of life history information for more stocks.

Fishery importance and ecosystem importance should affect the target frequency of assessments because of the improved fishing opportunity obtained by quickly tracking upturns in stock abundance, and conversely the fishery and ecosystem risk avoided by preventing acceleration of downturns.

Arguably, stock status could influence the target frequency because stocks that are known to be approaching an overfished or overfishing condition need to be watched more closely to enable ACL adjustments to avoid crossing into overfishing or overfished conditions. Because stocks that are approaching overfishing or overfished status will also tend to be stocks that have high fishery importance, and because a stock's status is constantly changing, it seems preferable to use fishery importance in setting the target assessment frequency and then use stock status in the prioritization step as a tie-breaker among stocks that are equally due for assessment. While stocks that are on rebuilding plans, or approaching an overfishing or overfished condition need somewhat more frequent updates because these conditions are indications of changing stock abundance or fishing mortality rates, the prioritization system should ward against excessive diversion of assessment efforts from healthy stocks that are supporting major fisheries. Doing so will weaken tracking of these stocks and hinder close tracking of their available yield. The proposed system will prevent this diversion because the years overdue will be a primary factor in setting assessment priorities.

3.2.7 Experience with management procedures in the USA

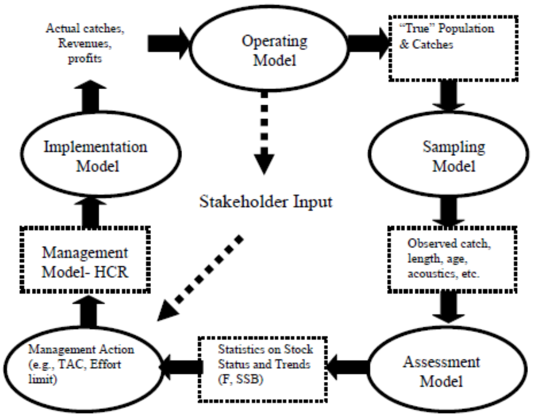
3.2.7.1 Definition of a management procedure (MP)

MSE (management strategy evaluation) is a general framework aimed at designing and testing MPs (management procedures) which specify decision rules and formulae for setting and adjusting TACs or effort levels to achieve a set of fishery management objectives (see Holland, 2010). Simulation testing is used to determine the extent to which an MP is robust to uncertainty. Butterworth, Cochrane and De Oliveira (1997) define an MP as a simulation-tested set of rules used to determine management actions, in which the data, the data analysis and stock assessment methods if applicable, as well as the harvest control rule (HCR) are unambiguously specified in advance.

<u>Note that an HCR, which might be something like setting the TAC to achieve a specified constant fishing mortality rate, is not itself considered an MP</u>. An MP must also specify the data and assessment methods for determining how the TAC that achieves that fishing mortality rate is actually calculated.

The MSE framework and MPs were first developed by the Scientific Committee of the International Whaling Commission during the 1980s (Punt and Donovan 2007) and have been applied to a number of fisheries since, predominantly in South Africa, New Zealand and Australia. An MP is an outcome of an MSE. The following figure illustrates the MSE process:

Figure 1: Schematic of a management strategy evaluation model



Referring to the above figure, note that an operating model is used to generate 'true' ecosystem dynamics including the natural variations in the system. Stock assessments of historical data supply the basis for the operating models (OMs). Data are sampled from the operating model to mimic the collection of fishery dependent data and research survey data respecting their inherent variability and statistical properties. These data are then passed directly to the MP. This MP may include a stock assessment as part of the annual TAC determination process, although this is seldom the case since **one of the main appeals of MPs is that annual stock assessments are not required** (this appears to be a misconception in the above figure in Holland, 2010). If the MP includes a stock assessment as part of the calculation of the TAC, then the figure as above is correct, but normally the stock assessments only play a role to frame the operating models.

Based on the data and the MP a management action is determined (e.g., a change in the TAC). Fleet effort and catch are then modelled, ideally accounting for potential error in implementation, and resulting catches are fed into the operating model. By repeating this cycle the full management cycle is modelled. It is possible to compare the performance of the MP across a range of performance measures such as long term catch, inter-annual catch variability, effort levels, catch size structure and more. Thus alternative MPs are compared by running many stochastic simulations for several years to identify the performance of a rule according to different metrics under a likely range of conditions. The objective is to identify MPs that perform well under the range of conditions based on the pre-determined objectives and constraints.

The MP should include a set of meta-rules that specify in advance the actions in response to exceptional circumstances that might arise necessitating deviation from the MP advice, or initiating a fresh MSE. These circumstances may include such eventualities as the survey of CPUE change fall outside the range of predictions encountered during the MSE, or a range of possible external impacts not accounted for in the MSE.

The MSE approach and use of MPs to determine regular management actions has several potential advantages over the traditional pattern of regular or periodic stock assessments followed by TAC determination (Geromont et al. 1999). The MSE approach is expressly aimed at identifying MPs that are robust to natural variation in the system and to uncertainty and error, both in stock assessments and implementation. The analysis usually attempts to identify rules that perform well under a variety of potential future circumstances and with uncertainty in assessments. Often, when there are uncertainties about the underlying stock structure or important processes such as migration or recruitment, an MP may include simulations with multiple variations of the operating model to test the robustness of the MP given alternative model structures.

3.2.7.2 USA review

Holland (2010) reviews the experience in the USA with management procedures. He notes that it is common practice in the US to simulate rebuilding trajectories associated with alternative harvest strategies to find ones that meet legal requirements to rebuild by the target date with at least a 50% probability. However, although the simulations carried out to evaluate such rebuilding plans typically allow for stochastic future recruitment and may also account for uncertainty in the current size and age structure of the fish stock, they cannot be considered to be MPs because they do not generally specify the variance in the future data used to determine the TAC. Furthermore, in the USA harvest control rules do not assess the performance of the harvest strategy against a set of performance measures reflecting objectives elected by managers and stakeholders.

Although there is growing interest in applying the MSE approach in the US, there are very few examples of using an MSE framework to evaluate a realistically implementable MP for fishery rebuilding. The only exception mentioned by Holland (2010) is an MSE designed to explore rebuilding strategies for West coast rockfish (see Punt and Ralston (2007)), for several overfished rockfish stocks managed by the Pacific Fishery Management Council (PFMC). That analysis was however not designed to lead to implementation of an MP, and was just an exercise to demonstrate the performance of alternative HCRs (harvest control rules). Consistent with the MSE approach, the simulations modelled uncertainty and stochastic variability in the underlying biological system and uncertainty in the assessments used to set TACs in the simulations.

In the US the use of MSE and MPs is inhibited by a number of factors. As in most countries, fisheries managers typically lack the resources to undertake an MSE in addition to the normal data collection and stock assessment process. Most US fisheries also do not have commercial stakeholder organizations that can legitimately represent the interests of the overall commercial fishery and agree on a particular MP. This is important because a lack of agreement on the MP up front could lead to political pressure to drop it if it leads to greater TAC reductions or slower increases than desired by some groups.

MPs represent a significant departure to the normal HCR process based on biological targets such as F_{MSY}, F_{MEY}, B_{MSY} or B_{MEY}. Thus although the MSE will consider the performance of the resource under an MP, it is seldom the case that “target reference point based HCRs”, structured as MPs, perform particular well or better than a range of other MPs. Indeed why should they. So in jurisdictions where MPs have been applied (e.g. South Africa) the structure of the MP has seldom if ever resembled a traditional HCR cum biological target reference point. Because the MSE assesses MP performance over a long planning horizon of 10 or 20 years, it is typical that such time sequences contain instances when a TAC “decision” violates the decision that a traditional “HCR cum biological target reference point” would make. This is a potentially serious problem in jurisdictions where the biological target reference point is bureaucratically or even legally codified.

Thus in the USA it is not clear whether an MP would legally be allowed if it could result in fishing mortality exceeding F_{MSY} at some point in time. Nevertheless there is growing interest in MSE in the US, at least as a means to evaluate HCRs for robustness to uncertainty. Holland (2010) concludes that as more fisheries adopt catch share systems with clearly defined stakeholders and hard catch limits, interest in developing MPs is likely to grow.

3.2.8 Survey frequency considerations

This review did not encounter a specific policy statement about the frequency of surveys appropriate for different stocks, or their prioritization, in the USA. A number of case specific investigations of the trade-offs of a reduction in the frequency of surveys were sourced. AN example is AFSC (2011) which is an unpublished study on groundfish and crab surveys in the northern Pacific. AFSC (2011) examines the short term consequences of survey reduction using a retrospective analysis approach by dropping past surveys from existing assessments in order to assess the conservation and economic impacts that might be expected under reductions in survey effort. This document suggests the following impacts:

Impacts on target species include:

1. Decreased precision in biomass estimates resulting in increased uncertainty in ABCs (allowable biological catches)
2. Foregone economic opportunities (e.g., for eastern Bering Sea pollock, Bering Sea yellowfin sole, and snow crab combined, total of $147.8 million in lost revenues if the 2010 survey had not been conducted). Potential annual economic losses for all stocks combined could be quite large
3. Increased inter-annual variation in ABC recommendations that could lead to loss of market share or increased costs to industry
4. Higher risk of overfishing, particularly for stocks with declining population trends
5. Fishery revenues could be reduced for several years following overharvest if stocks require rebuilding
6. Potential loss of MSC certification (with potentially large costs, see for e.g. Lallemand et al (2016))
7. Loss of important biological information on age, growth, spatial distribution, and maturity needed for stock assessment that may affect ABCs in a variety of ways

Impacts on ecosystem-based management include:

8. Inability to spatially apportion catches in SSL foraging areas (e.g. GOA pollock and BSAI Atka mackerel)
9. Loss of ability to assess non-target species, many of which directly depend on survey biomass estimates for ABC/OFL specifications
10. Loss of important information needed to advance understanding of climate links to fish production, distribution and predator-prey interactions
11. Loss of information needed to produce Fishery Ecosystem Plans and Integrated Ecosystem Assessments – key components of providing ecosystem based advice to fishery managers. Information used to write IEAs and the Ecosystem Considerations chapter for the Council are dependent upon data collected on both survey and other non survey cruises (e.g. Climate and Ecosystem cruises).AFSC groundfish and crab surveys and their role in fisheries management

3.2.9 Ecosystem approach to fisheries management (EAF)

Some early concepts about EAF and EBFM (Ecosystem Based Fisheries Management) are reflected in Fluharty and Cyr (2001). They document eight principles about our understanding of fisheries ecosystems, viz.

1. The ability to predict ecosystem behavior is limited.
2. Ecosystems have real thresholds and limits which, when exceeded, can aflect major system restructuring.
3. Once thresholds and limits have been exceeded, changes can be irreversible.
4. Diversity is important to ecosystem functioning.
5. Multiple time scales interact within and among ecosystems.
6. Components of ecosystems are linked.
7. Ecosystem boundaries are open.
8. Ecosystems change with time.

They also enunciate 6 policies that can be used to promote EAF or to assess whether EAF is presently being applied, i.e.

1. Change the burden of proof from only restricting fishing activity once unacceptable impact has been demonstrated to only allowing fishing activity if a reasonable expectation is that unacceptable effects will not occur.
2. Apply the precautionary principle
3. Purchase “insurance” against unforeseen, adverse ecosystem impacts, e.g. via MPAs
4. Learn from management experience
5. Make local incentives compatible with global goals
6. Promote participation, fairness and equity in policy and management.

Fluhary and Cyr (2001) recommends that each council in the USA fisheries management system develop an FEP (Fisheries Ecosystem Plan) as a mechanism for incorporating ecosystem principles, goals and policies into existing fisheries management structures and approaches. Each FEP should

1. Delineate the geographical extent of each ecosystem within the relevant council’s authority
2. Develop a conceptual model of the food web
3. Describe the habitat needs of different life-history stages for all plants and animals that represent the “significant food web” and how they are presently considered in conservation and management measures.
4. Calculate total removals including incidental mortality and relate these to inter alia standing biomass and production
5. Assess how uncertainty is characterized and what kind of buffers against uncertainty are included in conservation and management actions
6. Develop indices of ecosystem health as a target for management.
7. Describe available long-term monitoring data and how they are used.
8. Assess the ecological, human and institutional elements of the ecosystem which most significantly affect fisheries.

Finally, Fluhary and Cyr (2001) recommends a) a series of short term actions and b) legislative reforms.

Fast forwarding 13 years, NOAA (2014) is a report by the Ecosystem Sciences and Management Working Group (ESMWG) assessing the progress toward implementation of Ecosystem-Based Fishery Management (EBFM) in the United States regional fisheries management council system during the period 1999-2014, as well as the status and use of ecosystem science in management. This assessment is quite strongly based on the recommendations and proposals in Fuharty and Cyr (2001) with some changes as is understandable given the time intervening since then. The measurement items and compliance level by number of councils are as follows:

1. Cease overfishing and develop rebuilding plans for overfished species. 4 x stopped overfishing, 2 x some species still overfished, 2 x no plans in place.

2. Delineate extent of ecosystem/interactions. 3 x under discussion, 5 x have given formal recognition.

3. Develop a conceptual model of the food web. 6 x councils have model(s) available and which have been evaluated in stock assessments and management decisions, 2 x matter is under discussion.

4. Describe habitat needs of different life history stages of animals and plants in the “significant foodweb” and develop conservation measures. 5 x EFH (Essential Food Habitat requirements of the 1996 sustainable fisheries act) fully implemented, 3 x not used because MSA (Magnusson Stevens Act) constitutes a baseline.

5. Calculate total removals – including incidental mortality and relate removals to standing biomass, production, optimum yields, natural mortality and trophic structure. 4 x Incidental mortality insufficiently accounted for, 2 x compliance with MSA only, MSA requirements implemented with good estimates of incidental mortality.

6. Does council assess how uncertainty is characterized and define what buffers against uncertainty are included in management actions? 8 x Partial accounting of uncertainty and use of risk based assessments
7. Has council set an ecosystem goal[s] and developed indices of ecosystem health as targets for management? 2 x under discussion, 6 x ecosystem indicators not defined as targets.
8. Describe long term monitoring data and how they are used. 4 x regional monitoring plan for fisheries but not necessarily ecosystem based, 1 under discussion, 3 x region developed monitoring plan relative to EBFM can be identified 4 x regional monitoring plans for fisheries but not necessarily ecosystem based.
9. Assess the ecological, human and institutional elements of the ecosystem which most significantly affect fisheries, and are outside Council/NMFS jurisdiction and define a strategy to address those influences. 4 x fully proactive plan with respect to outside impacts, 1 x no plan but region is responsive to threats as they arise, 1 x limited or no response to external influences, 2 x region discusses but has limited engagement with outside influences.
10. Is there a Fishery Ecosystem Plan/ Fishery Management Plan employing EBFM? 2 x discussion of FMP for Fishery Management plan employing EBFM, 2 x FEP or FMP covering significant portions of the relevant ecosystem, 4 x FEP or thorough FMP using EBFM for the relevant ecosystem.
11. Does the Council have a lead entity designated to advance EBFM in the Council process? 6 x Yes, 1 x being developed, 1 x limited and no significant discussion.
12. Are ecosystem models developed and available for use in the Council process? 5 x Yes, 1 x No, 2 under discussion.
13. Are decision support tools for EBFM / trade-off analysis employed (e.g., Management Strategy Evaluation, risk assessments, ecosystem indicators, and scenarios)? 6 x yes to some of the elements, 1 x no and 1 x under discussion.
14. To what extent are spatial management tools applied [besides EFH measures above] to accomplish EBFM? 3 x some spatial tools applied to as well to EFH, 5 x significant.
15. Other. 1 x ACL-Cap on Total Removals, 1 x EBFM initiative agenda for council, 1 x Archipelago FMPs, 5 x no further commenting councils.

Table 8-10 is a summary of the progress towards EBFM by RFMOs to which the USA is a member (after NOAA, 2014).

3.2.10 USA: Protected Species Bycatch Management

The USA has a well developed set of regulations and procedures for monitoring and minimizing the impact of fishing on protected bycatch species. These are well documented by NOAA for the present day situation (see http://www.nmfs.noaa.gov/pr/interactions/).

3.2.10.1 Sea turtle incidental catch

The U.S. has two pelagic longline observer programs monitoring tuna and swordfish fisheries in the Pacific Ocean, one based in Hawaii and the other in California (CA). The Hawaii-based program began in 1994 and observer coverage averaged approximately 4% of fishing effort until 2000. In 2001, sea turtle conservation measures were implemented; therefore, a higher level of coverage was needed to adequately document effectiveness of those measures. The CA-based program has maintained nearly 12% coverage since its inception in 2001. Prior to the implementation of conservation measures, annual sea turtle catch in the Pacific was nearly 1,500 sea turtles per year. Catch has dropped significantly (100/year) since the measures were implemented. In the Atlantic Ocean, the U.S. has observed the pelagic longline fishery since 1992 averaging 2.5% to 5% annual coverage. Turtle catch estimates have ranged widely from 5 year to year (between 800 and 3,500) with high sea turtle interaction rates in the Gulf of Mexico through the mid-Atlantic and Grand Banks.

The U.S. has implemented several measures to reduce bycatch in domestic longline fisheries. The U.S. has implemented regulations to control effort, mostly in the swordfish fishery, such as prohibiting shallow sets in areas of Atlantic and Pacific Oceans. A tuna fishing closure also occurs in Pacific during certain times of year. In addition, the U.S. has conducted and supported research on gear modifications to reduce sea turtle bycatch over the last 3-4 years, finding that large (18/0) circle hooks and the use of different bait combinations have been very effective at reducing sea turtle bycatch. Work by NOAA at an international level has included, as an example the following:

In 2000 NOAA developed a strategy to address sea turtle bycatch in global longline fisheries. The objectives were to quantify sea turtle bycatch and to share bycatch data with the global community. Key to these objectives was the standardization of data collection methods and the identification of critical data elements as well as the development and implementation of solutions to reduce bycatch. Fora used to achieve these objectives included the United Nations Food and Agriculture Organization (FAO), Regional Fisheries Management Organizations (RFMOs), and bilateral fisheries discussions.

In February 2003 NOAA convened an International Technical Expert Workshop on Marine Turtle Bycatch in Longline Fisheries aimed at establishing standards for data collection through observer programs, identifying minimum data elements, and establishing regional and international fora for sharing and standardizing sea turtle bycatch data.

3.2.10.2 Seabird Bycatch

There are both international and national instruments in place for the management of seabird interactions and mortality. For instance, as part of the FAO's Code of Conduct for Responsible Fisheries, there are related international plans of action (IPOA) for several fisheries issues and species groups of special concern. The International Plan of Action for Reducing the Incidental Take of Seabirds (IPOA-Seabirds), adopted by FAO in 1999, calls for longline fishery assessments to be conducted. Member nations with incidental catch of seabirds should develop a National Plan of Action (NPOA).

NPOA Seabirds NOAA (2014) provides a summary of progress by the USA in addressing seabird bycatch issues since the 2001 NPOA was published. It records that interagency collaboration has been a large part of U.S. success in reducing the incidental catch of seabirds. Three different agencies – the National Marine Fisheries Service, the Fish and Wildlife Service, and the Department of State – play complementary roles in implementing the NPOA-Seabirds. These agencies have made great efforts to coordinate research and action on seabird incidental catch mitigation. Management measures taken by the United States include the introduction of comprehensive regulations for avoiding the incidental catch of seabirds in a number of domestic fisheries. Such regulations have resulted in a halving of or even tenfold decrease in incidental catch numbers in certain fisheries. Additionally, the United States actively supports the adoption of seabird management measures in international forums, and is pursuing accession of the Agreement on the Conservation of Albatrosses and Petrels (ACAP). Finally, the United States has implemented a number of outreach and educational tools to combat seabird bycatch by developing easy reference guides and manuals for fishermen and fisheries observers. Despite the strides it has made in reducing incidental seabird catch in longline fisheries, the United States recognizes that there are further steps and initiatives it can take. Among these include the recognition that while incidental catch may have decreased in longline fisheries, it is still an issue in gillnet and trawl fisheries. In addition to further research and interagency collaboration, the United States will strive to emphasize the importance of seabird populations in ecosystem-based management systems and continue to promote global seabird conservation through the adoption of international measures.

NOAA Hawaii (2014) gives a comprehensive summary of seabird mitigation measures, observer programmes and practices and outcomes for the Hawaiian longline fleet and represents a good example of the standards and procedures set by the US in this area. The following table gives a summary of mitigation methods employed:

1. How do you set your gear →	STERN-SETTING		SIDE-SETTING	
2. Do you shallow-set or deep-set, and where are you →	Shallow-Set Anywhere	Deep-Set North of 23° N	Shallow-Set Anywhere	Deep-Set North of 23° N
3. What you need to do ↓				
Deploy mainline from port or starboard side at least 1 m forward of stern corner			Yes	Yes
If line shooter is used, mount it at least 1 m forward from stern corner			Yes	Yes
Use a specified bird curtain aft of the setting station during the set			Yes	Yes
Deploy gear so that hooks do not resurface			Yes	Yes
Attach 45 g or heavier weights within 1 m of hook of each hook		Yes	Yes	Yes
Use a line shooter to set the mainline		Yes		
Keep two 1-pound containers of blue-dye on boat	Yes	Yes		
Use completely thawed and blue-dyed bait	Yes	Yes		
Keep fish parts and spent bait with all hooks removed for strategic offal discard	Yes	Yes		
Cut all swordfish heads in half, and use heads and livers for strategic offal discard	Yes	Yes		
Night Set - begin set 1 hour after local sunset and finish 1 hour before next sunrise and keep lighting to a minimum	Yes			

And the amount of fishing effort and observer coverage is summarized in the following table:

2012

	Deep-set fishery	Shallow-set fishery
Number of vessels	128	18
Trip	1,361	84
Sets	18,113	1,353
Hooks	44,061,911	1,449,246
Observer coverage	20.4%	100%

2011

	Deep-set fishery	Shallow-set fishery
Number of vessels	129	20
Trip	1,306	83
Sets	17,155	1,474
Hooks	40,719,827	1,505,467
Observer coverage	21%	100%

Source: NMFS PIFSC logbook data, unpublished; NMFS observer program

A summary of interactions is as follows:

Year	Laysan albatross	Black-footed albatross	Sooty shearwater	Other or unidentified bird species caught	Total birds observed caught	Birds released injured and alive	Birds released dead	Total observed effort (hooks)	Seabird interaction rate (birds per 1,000 hooks observed)
Deep-set									
2004	2	5		2	9		9	7,868,613	0.001
2005	6	11		1*	18		18	9,328,681	0.002
2006	1	17	5		23		23	7,437,498	0.003
2007	7	18			25		25	7,728,502	0.003
2008	14	30	14	2**	60	4	56	8,747,496	0.007
2009	18	23	4		45		45	7,872,668	0.006
2010	39	17	1		57	1	56	8,161,800	0.007
2011	32	13	3		48	2	46	8,314,744	0.006
2012	31	36	7		74	5	67	8,845,848	0.008
Shallow-set									
2004	1				1	1		115,718	0.009
2005	62	7			69	47	22	1,358,247	0.051
2006	8	3			11	5	6	676,716	0.016
2007	40	8			48	40	8	1,353,761	0.035
2008	33	6			39	24	15	1,460,042	0.027
2009	81	30	1		112	88	24	1,694,550	0.066
2010	40	38		1***	79	61	18	1,832,471	0.043
2011	49	19			68	53	15	1,505,467	0.045
2012	62	37			99	77	21	1,476,969	0.067

Note: Data are based on the date and time of the beginning of the haul. Interaction rates are rounded to the nearest thousandths (third decimal) place.
*Footnote: *brown booby; **red-footed booby and unidentified seabird; ***Northern fulmar. Source: NMFS PIRO Observer Program.*

In addition to operational requirements to reduce or deter seabird interactions, owners and operators of pelagic longline vessels must complete a protected species workshop each year. The workshop includes training in sea turtle, marine mammal, and seabird identification, safe handling and release techniques, and a review of regulatory requirements and compliance updates. In a classroom setting, fishermen learn from oral presentations, hands-on demonstrations, videos, and printed reference materials. NMFS also offers workshops online. A valid workshop certificate is necessary for owners to receive and annually renew Federal longline fishing permits. Longline vessel operators must also have on board the vessel a valid protected species workshop certificate issued by NMFS to the operator of the vessel.

3.2.10.3 Marine Mammal and Endangered Species Bycatch

The Marine Mammal Protection Act (MMPA) requires reduction—approaching zero mortality rates—in the bycatch of marine mammals.

Recent amendments to the MMPA require the establishment of collaborative take-reduction teams (TRTs) charged with developing both short- and long-term take reduction plans and strategies for marine mammal stocks. Team membership includes commercial and recreational fishing industries, fishery management councils, interstate commissions, academic and scientific organizations, state officials, environmental groups, Native Alaskans or other Native American interests if appropriate, and NMFS representatives.

TRTs have immediate and long term goals:

1. The immediate goal of a take reduction plan is to reduce, within six months of its implementation, the incidental take of marine mammals below the level that impedes the stock's ability to reach or maintain its optimum sustainable population.
2. The long-term goal of a take reduction plan is to reduce, within five years of its implementation, the incidental take of marine mammals to insignificant levels approaching zero mortality and serious injury rates.

To date, five TRTs have been established: (1) the Gulf of Maine Harbor Porpoise TRT, (2) the Pacific Offshore Cetacean TRT, (3) the Atlantic Offshore Cetacean TRT, (4) the Atlantic Large Whale TRT, and (5) the Mid-Atlantic Coastal Gill Net TRT.

Section 7 of the Endangered Species Act ESA requires that all federal agencies consult with NMFS regarding measures that can be taken to reduce impacts on endangered and threatened marine species. NMFS' own actions, such as the issuance of fishery management regulations also fall under this requirement. NMFS is engaged in ongoing consultations to establish measures for takes of endangered species that are likely to occur as bycatch in marine fisheries, such as selected species of Pacific salmon, harbor porpoise, monk seals, marbled murrelet, Steller sea lions, and sea turtles.

4 New Zealand

4.1 Fisheries Overview

New Zealand fisheries waters comprise the exclusive economic zone, the territorial sea, internal waters and freshwater or estuarine waters where fish, aquatic life or seaweed is found. This fisheries jurisdiction covers about 4.5 million square kilometres and is the fourth largest EEZ in the world. The marine waters are characteristically very deep with 72% of its waters deeper than 1000 metres, 22% between 200 and 1000 metres and only 6% less than 200 metres.

Most commercial caught fish are in waters shallower than 1 200 metres. A wide diversity of marine species live in New Zealand fisheries waters. They include approximately 1 200 species of fish, 2 400 species of molluscs, 2 000 species of crustaceans, 600 species of echinoderms and 900 species of seaweed. Around 130 species are fished commercially, and around 100 species fall within the quota management system.

Around 750 000 tonnes greenweight of seafood is harvested annually (circa 2000). Seventy percent of this seafood is taken from deepwater and mid-water stocks, 11% from pelagic stocks and 10% from farmed species. Hoki, squid, southern blue whiting and jack mackerels provide the largest volumes of catch in the marine capture fishery. Hoki, rock lobster, orange roughy and squid are the most valuable.

4.1.1 Institutional Arrangements

There are three tiers of government in New Zealand: central, regional and local. Fisheries management is the preserve of central government and the Ministry of Fisheries administers the Fisheries Act 1996

The Ministry employs around 340 people in offices round New Zealand.

The Ministry is responsible for doing activities (grouped together into "outputs") for the Minister of Fisheries. Each year these outputs are negotiated with the Minister as part of the budget and planning process. The outputs reflect what the Minister and the Ministry think should contribute towards the objectives and strategies for fisheries. These outputs are grouped into classes with the following heading:

1. Policy Framework
2. Fisheries Information and Management
3. Regulatory Management
4. Fisheries Access and Administration

5. Enforcement of Fisheries Policies
6. Prosecution of Offences

The Ministry contracts the provision of certain services within these output groupings. For example, research services providers conduct a large proportion of stock assessment and biodiversity research under contract to the Ministry. Some fisheries administration activities (e.g., vessel registrations) have been devolved completely out of the Ministry and are conducted according to standards set by the Minister, i.e. the Ministry only conducts a performance-monitoring role.

The setting of management measures and decisions on the level and extent of the Ministry's fisheries services are subject to consultation with fisheries stakeholders (commercial, customary Maori, recreational, environmental). This consultation occurs as a matter of good administrative practice, and for many decisions is required by the Fisheries Act. Consultation is beneficial and can lead to improved decisions on management and fisheries services provision.

Improving value in the fishery means providing opportunities and institutional arrangements for stakeholder-led management. Fisheries management agencies generally do not have the information to manage all aspects of fisheries so as to maximise fishery value. Stakeholders are often better placed to determine the type of utilisation and protection that will maximise certain types of value in the fishery, provided they face the full cost of their actions. In particular, stakeholders often have better information about the likely costs and benefits of fisheries management, as well as an interest in selecting the management approaches that are either more cost-effective or are expected to give greater return.

Other laws relating to the management of marine life are the:

- Resource Management Act 1991, which is New Zealand's main environmental and planning law and is mainly administered by regional councils;
- Marine Reserves Act 1971, which provides for the establishment of marine reserves and specified areas in the territorial sea, seabed and foreshore to managed for scientific study and to preserve the marine habitat;
- Marine Mammals Protection Act 1978, which provides for the conservation, protection and management of marine mammals;
- Wildlife Act 1953, which protects certain marine species. The latter three laws are administered by the Department of Conservation.

4.1.2 Planning procurement and funding of research services

NZ Strategy Review (2010) outlines four areas in which the provision of research services needs to be improved to meet current and future demands:

a) **Planning and Prioritisation:** Current processes are too inefficient and are not aligned with the requirement for specification of fishery management objectives that direct the procurement of research.

b) **Procurement:** Current procurement approach no apparent long-term strategy and does not provide for optimum grouping of projects within single contracts. Providers and Industry want multi-year contracts. Processes are overly complicated with too many milestones and complex project tenders. New Zealand's small economy has a limited capacity to support competition in markets for most types of fisheries research. In particular, specialized services such as trawl surveys require a large capital investment, whilst the service demand is insufficient without access to other markets such as seabed mineral exploration. Significant, real and perceived barriers to market entry for new research providers.

c) **Funding Sources and Financial management:** Current approaches to funding within MFish and between sectors do not maximise funding contributions for fisheries research from diverse sources. A lack of clarity around the roles of MFish and DoC in respect to funding for protected species and aquatic environment research. Creates tensions around the cost recovery of aquatic environment research. Peaks and troughs of the annual cost-recovery levies results in financial management issues for some levy payers. General lack of transparency about allocation of MFish costs (particularly indirect costs) creates distrust between Industry and MFish.

d) **Miscellaneous Issues:** New Zealand has a low capacity for fisheries stock assessment science and research. The need to ensure efficiency and effectiveness in the $20M per year invested in obtaining and managing fisheries information.

NZ Strategy Review (2010) goes on to make 13 specific recommendations. Relevant to this review are the following points made in those recommendations:

- Ensuring that all research is aligned to achieving fishery management objectives.
- The development of robust decision criteria to guide decision-making around the procurement of fisheries services, including requirements to consider costs, benefits, environmental sustainability, and utilisation opportunities.
- The engagement of specialist capability in strategic procurement and contract negotiation for long-term supply arrangements. Related: Building transparency of the research procurement process, including involving non-MFish participants, in an advisory capacity in tender evaluations for large and/or significant multi-year contracts.
- Consider and evaluate direct purchase of research by stakeholders as an option for maximising value.
- Setting standards for the provision of research used in fisheries management, applicable to both MFish-purchased and non-MFish purchased research.
- Collaboration with the Foundation for Research, Science and Technology, Industry, research providers and universities to clarify responsibilities for developing stock assessment capability.

Table 8-9 illustrates procurement strategies in the New Zealand, based on a categorization of difference research services. It shows that different strategies will be required in markets for different types of research. For some research types the likely strategies appear obvious; for others they are less clear. Therefore, strategies for major markets for different types of research should be tested with current and potential providers to determine the optimum procurement strategy. Methods could include informal discussions and formal requests for expressions of interest for long term provision design.

4.1.3 *Assessment and management issues*

Mace et al (2014) notes that of the 636 fish stocks (spread among 100 species or species complexes) currently in the system, 288 are considered to be “nominal” or “administrative” stocks (species-area combinations for which the TAC is 0–20 t, or where a significant commercial or non-commercial potential has not been demonstrated). For the remaining 348 stocks, 77% of which have been in the QMS for 10–27 years, TACs for 57% have never been altered and there have been two or fewer changes for 89% of stocks. Only 16 of the 348 stocks have experienced five or more changes in TAC. The main reason for this inertia is the paucity of research and assessment information to inform quota changes, particularly for small stocks. Therefore, implicit constant catch scenarios are actually the norm and the legacy of the initial design of the system prevails.

For some key species, alternative approaches have been taken, including setting TACs based on projections of stock size under alternative TAC scenarios (e.g. hoki) or developing management strategy evaluations (e.g. rock lobster). In both of these cases, alternative scenarios are scientifically evaluated using performance measures related to the probability of stocks attaining management targets or falling below biomass limits. New Zealand's Harvest Strategy Standard (Ministry of Fisheries, 2008; Mace, 2012) defines MSY-based management targets and biomass limits that take account of variations in stock size. For example, management targets can be based on B_{MSY} or F_{MSY} or proxies thereof, but these targets are explicitly defined as levels around which stocks or fisheries are expected to fluctuate.

4.1.4 *Protected species bycatch*

Mace et al (2014): New Zealand took steps to reduce incidental captures of seabirds starting around 1990 and mitigation efforts have developed markedly since:

- A National Plan of Action (NPOA-seabirds) covering all New Zealand fisheries was published in 2004 and recently revised. New Zealand is Party to the Agreement on the Conservation of Albatrosses and Petrels (ACAP).
- Sea lion exclusion devices have been in use in trawl fisheries for squid to reduce captures of New Zealand sea lions since ~2000.
- Various area closures have been introduced to reduce captures of Hector's and Maui's dolphins in coastal trawl and set-net fisheries.

Protected species bycatch generates substantial controversy which is exacerbated by a lack of quantitative information. To balance the demand for information against the high cost of relevant data and research, New Zealand has developed increasingly comprehensive semi-quantitative risk assessments (sometimes called Level-2 assessments). New Zealand's current risk assessment for seabirds covers all commercial trawl, longline, and set-net fishing within New Zealand's EEZ. For each of 70 taxa, risk has been assessed as the estimated potential annual fatalities relative to potential biological removals, considering direct effects of commercial fishing within New Zealand waters but not other anthropogenic fatalities. Conversely, a semi-quantitative risk assessment including all anthropogenic threats (relative to PBR) was conducted for the critically endangered Maui's dolphin. A risk assessment across all New Zealand marine mammal species is underway. Fully quantitative population modelling to assess risks posed by fishing is expensive and data-hungry and has been conducted for only about six seabird species and two marine mammals. All assessments have been complicated by uncertainties about productivity and fishing-related fatalities.

4.1.4.1 *Other effects of fishing*

Discarding of unwanted parts of the catch has been identified as a significant issue in many fisheries worldwide, and few fisheries are without bycatch. When the QMS of New Zealand was introduced in 1986, it was presumed that fish bycatch would be dealt with through the need to have access to quota for all species of commercial importance, which is one reason most are now included in the QMS.

Total bycatch and discards are monitored for key offshore trawl and longline fisheries using observer and fisher-reported catch-effort information, but inshore fisheries have had low observer coverage and it has not been possible to assess levels of bycatch and discarding quantitatively in these fisheries. It has also been difficult to estimate unrecorded fishing-related mortality of non-QMS fish at a species level.

Bottom trawls and dredges are used to catch a relatively large proportion of commercial landings in New Zealand and can represent the only effective way of catching some species.

Seabed disturbance has consequences for biodiversity and ecosystem services, including fisheries production but little thought was given to such effects in the initial design of the QMS. It was assumed that quota holders would focus on the methods that gave the highest economic return, but potential longer-term ecosystem repercussions were not considered.

In recognition of the effects on biodiversity and fish nursery areas, certain coastal areas with particularly dense emergent invertebrates (known to be particularly susceptible to fishing disturbance) were closed to bottom trawling and dredging in the 1990s.

Outside the Territorial Sea, 18 seamount closures were established in 2000 to protect 25 representative features covering 81 000 km^2 of the EEZ from all bottom trawling and dredging. In 2007, Benthic Protection Areas covering ~1.1 million km^2 (30%) of New Zealand's EEZ were closed to trawling on or close to the bottom following an initiative by the New Zealand fishing industry. Fine-scale reporting by most trawlers using the EEZ since 1989 and by almost all trawlers since 2007 allows **the footprint of bottom trawling** to be monitored and compared with broad-scale habitat classifications.

4.1.5 Mace continued: Outcomes for fisheries science and research

In New Zealand fisheries science has evolved to include

- trawl and acoustic fisheries-independent surveys,
- state-of-the-art stock assessment models,
- management strategy evaluations,
- research on the environmental effects of fishing and biodiversity,
- comprehensive risk assessments,
- adoption of a Harvest Strategy Standard, and
- the adoption of a Research and Science Information Standard that sets out the role of science working groups and other forms of peer review to ensure the quality of the science.

In 1994 an original levy system was changed to a cost-recovery system in which the costs of research, compliance, and a few other government-provided services are explicitly billed to quota holders. Although at the outset funding for all research was invoiced to individual quota holders pro rata to quota, in 2001 a system of cost-recovery at the level of individual research projects was implemented with costs being recovered only from relevant quota based stake holders. Although this has worked well for some high-valued species—such as hoki and rock lobster— it has disadvantaged low productive / abundance species.

A further complication has been the introduction of contestability for research aimed at driving down what were perceived to be the unnecessarily high costs of science. However, the small population size of New Zealand and the limited funding for fisheries research has meant that only a few small, "niche providers" have entered the research market, and a large proportion of fisheries research is still conducted by NIWA. The combination of cost-recovery and contestability has also made it difficult to ensure the financial viability of the country's dedicated deepwater and inshore research vessels.

In addition cost-recovered research invoiced to fishing companies has frequently been perceived as a target for decreasing commercial costs when other options have not existed. As a result, most species have received little if any research attention for many years, and the overall fisheries research budget has decreased considerably—to ~50% of the level of the early 1990s. At the same time the number of species and stocks in the QMS has increased 3.5-fold, as has the need for research on recreational fisheries, the environmental effects of fishing, and international fisheries research obligations.

This has resulted in higher priority being afforded to stock monitoring and stock assessment modelling on high-valued species and considerably less priority being given to basic biological research on either high- or low-valued species. Some basic biological information on stock structure, growth, and recruitment dynamics has not been updated since the 1960s or 1970s.

The decrease in government research funding has been partially compensated by industry-initiated research and collaborative government-industry research surveys. However, this has occurred mostly in larger deep-water fisheries and represents only a small proportion of the shortfall in required funding and research.

4.1.6 Methods for stock assessments and management in data poor fisheries

There is growing interest from MPI and other fisheries stakeholders in methods to assess New Zealand fish stocks with low levels of data. While some preliminary work has been done in New Zealand, this review did not find the presence of a formal decision making process around data poor stock and the approaches that should be followed. Edwards (2014) gives an overview of data-poor methods in use internationally, drawing in particular on those presented at the world conference on stock assessments methods (WCSAM) held in Boston MA, USA, in July 2013. Reference is also made to interesting presentations from the Knowledge Based Bio-Economy (KBBE) workshop in Hobart TAS, Australia, in November 2013.

Based on the above, the New Zealand experience as far as it is reviewed here is not particular illuminating on this topic

As an addition to the comment made above about the situation in New Zealand, there are a large number of sources which document and recommend approaches to the assessment and management of data poor fisheries. Trophia (2010) and Geromont and Butterworth (2014) recommend the use of the MSE / MP framework for developing approaches to the management of data poor resources. Quoting from Trophia (2010):

"*Most of the management procedures that have been developed around the world are for valuable, data-rich fisheries. These fisheries usually already have sophisticated stock assessment models and often these have been used as the basis for management procedure evaluations. How can management procedures be evaluated for less valuable, data-poor fisheries for which there is insufficient data for a stock assessment? Although management procedures for data-poor fisheries are likely to be simpler than those for data-rich fisheries, they can still be evaluated using the same, often sophisticated, simulation approach. However, rather than using stock assessment as the source for parameter estimates and their associated uncertainty, these values can be based on prior knowledge. Basic biological knowledge, such as the value of growth parameters, are often available for the species, either within the fishery, or for elsewhere. The simulated ranges for these and other parameters can then be based on "educated guesses". Although this will involve a degree of subjectivity, as long as there is an honest appraisal of the uncertainty around parameters, this can be preferable to relying solely upon the estimates of uncertainty from a stock assessment which, depending upon how that model was fit, may be unrealistically narrow*."

The dominant recommendation is therefore to use an MSE / MP approach to develop and / or validate short cut methods for the assessment and/or management of data poor stocks. Such methods have previously been employed in assessing the present tier structure for harvesting strategies for SESSF stocks (for example Knuckey et al, 2008). An important question is whether to pursue the development of generic data poor approaches that are applicable to entire classes or groups of stocks, as is the case for the SESSF, or whether perhaps to tailor the approach for a given stock and data collection situation (e.g. frequency and quality of FIS). Quoting Smith et al (2009), Geromont and Butterworth (2014) argue that " a generic approach is required for data poor stocks where similar species are grouped together in "baskets" according to their longevity/productivity and perceived depletion levels".

Geromont and Butterworth (2014) consider and compare the performance of five different types of MPs using artificially generated data and a simulation approach - for each type a range exists due to different values chosen for critical control parameters. The five types are a constant catch MP expressed as a percentage of the initial five year average recorded catch, two MPs based on length data, and two MPs which are based on CPUE data. The CPUE based MPs are clear winners. However the authors conclude that the MPs developed in their paper are only illustrative and need to be repeated to reflect more realistic levels of uncertainty for the group of stocks under consideration, and a wider range of variants regarding the underlying population dynamics for the operating models that were used.

A complication in the terms of reference of this study (i.e. this review document) is however the need to look at cost benefit trade-offs, for example how much catch must be forfeit or additional risk incurred if the survey frequency is reduced. This raises another dimension to the MSE process that must inform management. The harvest strategy for the SESSF tries to accommodate this with its tiered approach, but one wonders to what extent a pre-ordained framework can cope with an increasing number and variety of questions being asked about trade-offs under a variety of previously unexpected or unknown circumstances.

An alternative option to the approach recommended by Geromont and Butterworth is of course to resort to case specific MSE / MP evaluations. On the face of it this is simply impractical. Our review of Holland (2010) has already pointed out that the development of MSE / MP approaches in the USA are inhibited by the work load and level of expertise required. It is important to appreciate that the MSE / MP approach is a very involved process when it comes to data rich stocks. However, the MSE / MP approach is not necessarily onerous in the case of data poor stocks because in this case the MSE / MP approach does not need to deal with all the nuances of the statistical variability of the multiplicity of data sources encountered for data rich resources.

There is thus in our view the potential to develop “canned” MSE / MP applications which can be used to explore whatifs and compare MPs for many cases on a case specific basis with low levels of input, or even perhaps for a basket of cases, with functionality that does not require the user to be a specialist in the MSE / MP approach. This is a suggestion for consideration for Australian fisheries management, however there is no literature that was sourced as part of this review study that mentions this possibility. Such a solution mirrors the “canned” stock assessment approaches that are in vogue in certain jurisdictions.

4.1.7 Electronic monitoring in New Zealand

McElderry et al (2011) reports on a pilot level investigation into the efficacy of electronic monitoring in the inshore trawl fishery. The objectives of the study included determining the feasibility of EM data to determine and record:

a) Protected species retrieved
b) Rate of occurrence and number of protected species observed around the sterns of the vessels
c) Number of seabird interactions
d) Lowest level of identification possible for protected species
e) Deployment of a mitigation device
f) Presence/absence and quantification of offal discharge and discards
g) Compare results with those from an on-board observer

- Provide detailed recommendations on optimal storage/archiving of EM sensor and image data that would allow for secure storage and future review or audit and any other recommendations relevant to future deployment of EM systems in New Zealand fisheries.

Each vessel was provided with a standard EM system consisting of a control box, a suite of sensors including GPS, hydraulic pressure transducer, winch rotation sensor and up to four waterproof armoured dome closed circuit television cameras. The control box continuously recorded sensor data, monitored system performance and controlled image capture according to pre-programmed specifications, and provided continuous feedback on system operations through a user interface. Setup is illustrated below:

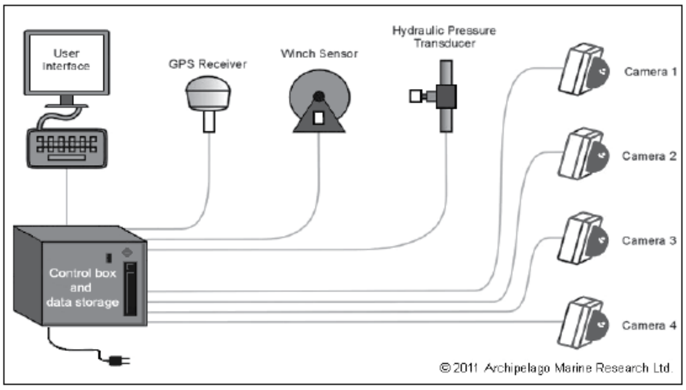


Figure 2. Schematic diagram of the electronic monitoring system.

Throughout the field trials, EM sensor data were sent to Archipelago's head office in Canada via a secure FTP site where the data were interpreted. The study drew the following conclusions:

Protected species in fishing gear: 94% of the fishing event imagery examined was usable for this purpose. It is important to adjust camera angles so that fishing gear is within the camera's field of view at all times - to improve the amount of usable imagery. It would however be difficult to distinguish specific items when they appear within a pile of catch unless they are large. It was not possible for EM to identify a dolphin in the fishing gear during a night haul when the catch was brought on board out of the camera's field of view. It is questionable whether a small, dead, water-soaked seabird would be detected

Protected species abundance: Imagery from 81% of fishing events examined was deemed usable. Dolphins were detected for several non-human-observed tows - but species identification was not possible for distances greater than about 5 m from the stern of the vessel. Compared with what observers could see, the EM resolution for assessment of seabird abundances is lower. The fixed field of view from cameras limits the ability to make an overall abundance estimate, as seabirds may move in and out of camera view. The cameras are also better able to resolve seabirds when they are contrasted against the sky or are directly astern of the vessel. Larger seabirds are more easily detected than smaller seabirds, and both are more difficult to resolve on the sea surface when conditions are rough. It is doubtful that EM would reliably resolve seabirds further than 25–50 m from the vessel.

Trawl warp interactions: None of the fishing event imagery was considered suitable for assessment of seabird interactions with the trawl warp. Cameras were not directly aimed at the trawl warp and its point of water entry, so the EM images did not record sufficient detail to enable seabird strikes to be monitored.

Protected species identification: There were two occurrences during the study where the bycaught animals were easily identifiable during EM review, and one reported event that could not be identified during EM review. Limited EM reviewer experience with New Zealand avifauna partly explains this result. For marine mammals, EM recorded sightings astern of the vessel, and the quality was high enough to enable species identifications. However, ideal conditions for species identification required close proximity to the vessel, calm seas and adequate lighting. It is quite likely that marine mammal interactions would escape detection under less favourable conditions. It is therefore **unlikely** that EM would be a robust tool for detecting and characterising protected species unless in close proximity to the vessel.

Mitigation device deployment: EM imagery was successful for observing the use of mitigation devices.

Assessment of discharge patterns: Most (85%) of the fishing event imagery examined in this study could be used for evaluating discharge patterns. For fishing events monitored by both an observer and EM, the level of agreement was within 16%.

Overall technical comments and conclusions: In the pilot study there were instances of a lack of a complete record of fishing trips, with the recommendations that there be more rigid guidelines for keeping the EM system powered up. There were problems with image quality, the most serious being poor image quality during night operations because of lack of light. Selection of camera location for optimal results is problematic (there were 4 cameras). Better communication between fishing industry and commercial vendors will in time improve outcomes. The following issues need to be addressed if EM technology is to be considered for use in the New Zealand inshore trawl fishery:

a) The monitoring agency (e.g. DOC) needs to carefully examine its monitoring needs and determine if they can be met using EM technology, taking into consideration the improvements suggested in this study.
b) The quality and effectiveness of EM monitoring is highly dependent on the establishment of good working relationships with the fishing industry
c) Communications and operational processes need to be improved to make EM more effective.
d) EM service technicians, fishing company management and vessel skippers and crew need to be able to communicate easily. EM technicians need to be more readily available so that they can respond to vessels quickly, and able to fit in at vessels' timetables at short notice.
e) EM data analysis services should be based in New Zealand to reduce cost, improve analysis timelines, improve data quality, and better integrate the analysis results with EM programme operations.
f) The optimal storage/archiving of EM sensor and image data requires further investigation.

4.1.8 Experience with management procedures in New Zealand

The relevance of the MSE / MP approach to fisheries management for this review is the potential for savings in the use of scarce analytical resources in the stock assessment and management process. The focus here is therefore not on the potential that this approach has for a more rational and explicit means of hedging risks and benefits in fisheries management in general.

Holland (2010) carried out a review level evaluation of the use of MPs in the New Zealand Rock Lobster Fishery. As in South Africa, the development and implementation of an MP in the NSS rock lobster fishery was facilitated by the institutional structure of New Zealand fisheries management and particularly the existence of commercial stakeholder organizations able to levy funds for research from quota holders and to engage in representative consultations with government. In New Zealand's Quota Management System (QMS), TAC changes are relatively rare and are extremely time-consuming for all parties. With over 97 species grouped into over 600 separate quota stocks, each with its own TAC, it is difficult to adjust TACs for many of them in any given year given the resources of the Ministry and stakeholders. MPs **greatly simplify this process** and allow the system to be much more responsive. The use of an MP in the management of the NSS rock lobster resource is viewed as a success, however based on this example it is clear that MPs do have large up front development costs.

The perceived success of MPs for managing the NSS rock lobster stock led to the development and voluntary implementation of an MP in the CRA4 (Wellington Hawke's Bay) quota management area on the South end of the North Island.

Despite the apparent success of the MPs implemented for rock lobster, there is no indication that MPs will see widespread use in New Zealand any time soon. An MSE was initiated to explore an MP for hoki in 2003, but was tabled after a decline in the stock due to poor recruitment forced large reductions in the TAC. The modelling work required for the design and evaluation of a new MP and the lack of monetary and human resources to carry them out is likely to inhibit all but a gradual uptake of MPs in the management system.

5 Canada

An analysis of recent information and pronouncements on relevant Canadian government websites shows that Canada is pursuing and intensifying a cost recovery program for the provision of fisheries services. The following sections are excerpts from those websites, selected to illustrate the source of this conclusion.

5.1 Monitoring

5.1.1 At-Sea Observers and Electronic Monitoring

"Beginning April 1, 2013, industry will assume the full costs of the At-Sea Observer Program nationally, as well as the Groundfish Electronic Monitoring Program in the Pacific Region.

Canada's At-Sea Observer Program places certified private-sector observers aboard fishing vessels to monitor fishing activities; collect scientific data; and monitor industry compliance with fishing regulations and licence conditions. The Department now has standards in place to designate individual at-sea observers and corporations seeking to provide at-sea observer services. A list of corporations certified by the Canadian General Standards Board and designated by Fisheries and Oceans Canada is now available for industry to engage.

The Pacific Region's Groundfish Electronic Monitoring Program uses multiple cameras and sensory devices onboard fishing vessels to monitor fishing activities; collect scientific data; and monitor industry compliance with fishing regulations and licence conditions. The Department presently has requirements for electronic monitoring set out in licence conditions and the Groundfish Integrated Fisheries Management Plan.

As part of this service delivery change, the Department is taking steps to review and update groundfish licence conditions and the Integrated Fisheries Management Plan to ensure that all electronic monitoring requirements are clearly established. The development of electronic monitoring standards through the Canadian General Standards Board, and Departmental designations against those standards, is not being pursued at this time.

5.1.1.1 What is changing?

Beginning April 2013 Fisheries and Oceans Canada will no longer share the costs of the at-sea observer program - nor will the Department pay any costs related to the Electronic Monitoring Program delivered in the Pacific Region.

Industry will now enter directly into contracts with at-sea observer service providers that are certified by the Canadian General Standards Board and designated by Fisheries and Oceans Canada.

Interested companies may continue to apply to the Canadian General Standards Board to become certified, and then, to the Department to become designated as a service provider for at-sea observer services.

As of April 1, 2013, industry in the Pacific Region will also now enter directly into contracts with electronic monitoring service providers that are approved by the Department as meeting the requirements for the provision of electronic monitoring services set out in the groundfish licence conditions and Integrated Fisheries Management Plan.

5.1.1.1.1 How will these changes benefit industry?

- Fishermen will have greater control over the operational elements of the at-sea observer program.
- Fishermen will have greater ability to select their at-sea observer or electronic monitoring service provider and negotiate fees for this service directly with the provider.

5.1.1.1.2 Will Fisheries and Oceans Canada play any role in this program?

- The Department will focus on monitoring and auditing the program to ensure data integrity and continued industry compliance.
- The Department will also be responsible for standard setting and service provider certification and approval.

5.2 Electronic Logbooks

Section 61 of the *Fisheries Act* requires that fish harvesters keep a record of their catches and fishing efforts and convey them to Fisheries and Oceans Canada (DFO).

Electronic logbooks client applications (e-logs) will enable fish harvesters to transmit to DFO fishing catch and effort information using electronic files. E-log client applications will be developed by the software industry and validated byDFO.

DFO, in collaboration with the Canadian General Standards Board (CGSB), a component of the Government of Canada, Public Services and Procurement, is working on a new DFO Standard on electronic logbook client applications. The new DFO standard will be used to evaluate electronic logbook client applications to be submitted for qualification. (circa 2016).

5.3 Paper Logbooks and Other Data Collection Forms

On January 1, 2013, fish harvesters across Canada assumed responsibility for obtaining their own Logbooks and/or Combined Forms. While DFO was able to provide its remaining inventory of logbooks to many participants in the 2013 fishing season, fish harvesters must now acquire these documents from a supplier.

6 South Africa

6.1 Fisheries Overview

South Africa has a well-established wild capture fishery sector. Wild capture fisheries currently includes three distinct components: commercial, recreational, and subsistence fisheries, each of which requires specific research and management interventions.

The commercial fishing sector can be broken down into highly industrialised capital intensive fisheries, which generally operate in deep water (e.g. hake trawl and pelagic purse seine fisheries) and near shore fisheries that are more easily accessible and use more traditional types of gear (line fishery and nearshore rock lobster hoop net fishery).

The following list describes the main fisheries in South Africa.

1. **Abalone – Inshore fishery:** mainly because of its unique situation with respect to the scale of the illegal fishery, and the potential that exists if this can be reduced.
2. **Agulhas soles – Trawl fishery**. Previously an important fishery, it is now dwarfed by hake. Catches recently were less than 500 MT p.a. (cf. ~150 000 MT tons p.a. for the hake resource). This fishery overlaps with the Hake inshore trawl fishery below.
3. **Cape hakes**: South Africa's most valuable marine fishery, with landings of ~ 150 000 MT p.a. This includes 4 sub-fisheries, the Deep Sea and inshore trawl fisheries and the longline and handline fisheries although the last 2 are marginal. Comprises two species, an inshore and an offshore species.
4. **Cape horse mackerel**: A relatively new fishery, very valuable. By value could make the cut as a major fishery. Not considered to be major for this study as it is an alternative catch in the demersal trawl fishery but at a relatively small tonnage. The dedicated mid-water trawl

fishery focusses on a single very large vessel (the Desert Diamond). The juvenile horse mackerel bycatch in the small pelagics fishery is limited by a bycatch management procedure to protect the biomass available to the directed mid-water trawl fishery. Has recently collapsed but unclear whether this is an availability issue or a reduction in resource abundance.

5. **Large pelagics**: Tonnages are relatively low, few operators involved. Tuna and swordfish Longline is capital intensive but representing less than 3% of the overall value of the South African fisheries.
6. **Traditional Linefish**: Arguably the second most valuable fishery taking all direct, indirect and recreational impacts into account. Also because of its interactions with other fisheries, the large number of often poor fishers and allied communities concerned, and the potential for benefits to be obtained by rebuilding stocks.
7. **Netfish**: Trek, gillnets and beach seine. Is being phased out by DAFF and has low value and impact overall at present. It accounts for 0.1% of the overall value of the South African fisheries.
8. **Oysters**: This is a relatively small fishery which we judge to be a low priority area for this review.
9. **Patagonian toothfish**: Patagonian toothfish is exploited by JV arrangements with two foreign vessels linked to two South African quota holding companies. Fishing takes place in the Southern Ocean in both the high seas (CCAMLR jurisdiction) and the South African EEZ around PEMI (Prince Edward and Marion Islands). Annual Catch < 500 MT
10. **Prawns**: A relatively small fishery, and dwindling. There are only a few boats involved in KwaZuluNata (KZN). Few people are involved.
11. **Seaweeds**: Small fishery.
12. **Sharks** Small demersal fishery
13. **Small pelagic fish (sardine, anchovy and round herring):** This fishery is rated as major because it is formally South Africa's second most valuable fishery (although some argue this for the line fish fishery). It is certainly the largest fishery by volume.
14. **South Coast rock lobster: Non-major.** About 500 - 600 jobs. This is an offshore capital intensive longline trap fishery involving 3 operating companies (many more rights holders), and about 7 large vessels. The annual tonnage is about 700 MT whole weight per annum.
15. **Squid.** A very valuable fishery in a good year when catches are about 10 000 MT. All exported. Large numbers of people are involved and it has a very high impact in the Eastern Cape
16. **Tuna Pole-Line:** With about 87 vessels and 106 rights holders, this low capital intensive fishery accounts for about 1.5% of the overall value of the South African fisheries.
17. **West Coast rock lobster:** A very traditional fishery with a huge impact for coastal communities on the West Coast and on the portion of the South Coast from Hangklip to Gansbaai (i.e. the South Coast west of Gansbaai). This includes 2 sub-fisheries, the offshore and nearshore west coast rock lobster fisheries
18. **White mussels and small invertebrates. Non-major**: Important source of protein for many communities, many issues, but value does not feature.

Figure 8-3 provides an overview of the status of South African fisheries.

New fisheries introduced since 1994 include:

- Large pelagics longline,
- Patagonian toothfish and
- An experimental fishery for octopus.
- Experimental targeting of lanternfish (myctophids).

6.2 Legislative and institutional arrangements, decision making structures

The advent of democracy in South Africa in 1994 led to a significant law reform process that affected all sectors including the fishing industry. The new South African Constitution, promulgated in 1996, was underpinned by human rights principles and sought to redress past injustices and promote substantive equality. These principles are clearly outlined in the Bill of Rights contained in the Constitution. All policies, legislation and governmental actions and measures are required to be formulated in terms of, and measured against these Constitutional rights and provisions.

In 1998, the Marine Living Resources Act (MLRA) was promulgated to give effect to the Marine Fisheries White Paper (1997). The MLRA replaced the Sea Fishery Act 12 of 1988 and together with its amendments in 2003 and 2013, is the main statute that regulates the management of South Africa's fisheries resources. It governs the management of all marine living resources except for sea birds and seals which are regulated by the Sea Birds and Seals Protection Act 46 of 1973.

The MLRA is applicable to South African waters and includes the seashore, internal waters, territorial waters, the exclusive economic zone, and the continental shelf as well as tidal rivers and lagoons. It also applies to fishing activities taking place in the waters off the Prince Edward Islands which form part of South Africa's territorial waters.

Of particular relevance to fisheries conservation is section 43 of the Act that empowers the Minister to declare Marine Protected Areas (MPAs). Certain activities such as fishing, or attempting to fish, constructing or erecting any building or other structure on or over any land or water within a MPA or discharging or depositing waste or any other polluting matter is prohibited in such areas. An area may be declared a MPA for the protection of flora and fauna, to facilitate fishery management or to diminish any conflict that may arise from competing uses in that area. Currently South Africa has 21.5% of its 3000km coastline under marine protection and 9.1% of these are declared as "no-take" MPAs.

6.3 Key governance actors and institutions

According to Schedule 4 of the Constitution, *marine resources* and thus marine fisheries are a national competence. DAFF, the Department of Agriculture, Forestry and Fisheries, is the department responsible for marine resources management. The Minister of DAFF administers the MLRA and has powers to pass regulations concerning a wide variety of matters concerning marine fisheries including conservation of marine resources and prescribing fisheries management and conservation measurements.

The DAFF chief directorates that play a key role in fisheries management are the Chief Directorates (CDs):

(1) Marine Resources Management,

(2) Research, and

(3) Monitoring, Control and Surveillance.

The CD: Marine Resource Management has three main Directorates namely;

- Directorate: Offshore and High Seas Management,
- Directorate: Small-scale Fisheries Management and
- Directorate: Inshore Fisheries Management.

The provisions of the MLRA are enforceable by Fishery Control Officers (FCOs), Honorary Marine Conservation Officers, and observers on vessels issued with a fishing licence. FCOs are recognized as peace officers (as defined in the Criminal Procedure Act 51 of 1977). They enjoy extensive powers within South African waters, FCOs can exercise power of hot pursuit, in accordance with international law.

Scientific advice on fisheries management is coordinated through the Scientific Working Groups, which are bodies appointed by DAFF and whose meetings are convened and coordinated by DAFF. SWGs consist of 8 members. The members are typically DAFF employees, but DAFF's main scientific consultants are also members on a number of the SWGs. Fishing Industry Associations attend the SWGs as observers. NGOs such as Coastal Links, or BirdLife South Africa, or Traffic or WWF also attend as observers, depending on the agenda items for particular meetings. Observers are allowed to make inputs. All attempts are made to make decisions by consensus. Where consensus is not achieved the matter is put to a vote. Only the 8 members may vote. If the vote is not 100% in one direction or another, then a minority viewpoint is recorded and "passed up the line".

The chairperson of the SWG drafts the SWGs recommendations and submits these to the Director of Research. The Director of Research does not have the power to change these recommendations, so is effectively a rubber stamp. In egregious cases the Director of Research could conceivably send it back to the SWG or the chair person, for example if the recommendations are poorly written. The Director of Research then sends the recommendation up to the Deputy Director General (DDG) for Fisheries. At the time of writing the Minister, DAFF, has delegated powers to the DDG Fisheries so that he/she can sign off on these recommendations. (The minister retains the power to recall this delegation). It is very rare for the Minister's or his/her delegated authority to deviate from the scientific recommendation.

Another structure involved in the decision making process are Management Working Groups (MWGs). These groups meet far less frequently but are intended to provide socio-economic and other input not available to the SWGs (which deal with scientific matters).

6.3.1 Monitoring approaches

Hutchings et al (2009) provides a summary of monitoring in the South African small pelagic, trawling and west coast rock lobster fisheries, as well as steps taken to pursue EAF. For small pelagics, fisheries dependent data include catch weight by species by 10 x 10 mile grids as well as biological data (fish length, weight, sex gonad maturity stage, gonad mass, otoliths for ageing, lipid content). Observers have been deployed at sea since 1999 on 8% of fishing trips. VMS is present on all pelagic fishing vessels with a recording rate of 6 hourly - these data are presently only used for compliance purposes to verify adherence to closed area regulations - the potential from VMS data at a higher frequency rate is recognized but has not been exploited yet. Fisheries independent hydroacoustic abundance surveys have been carried out since 1983. Both a spawner biomass and recruitment survey are run annually. The collection of ichthyoplankton samples during these surveys permits the application of a daily egg production method (DEPM) for biomass estimation, and dual hydroacoutics abundance estimates and DEPM abundance estimates were produced between 1984 and 1993. These showed good agreement over a period of 10 years. The DEPM was discontinued due to the additional workload, which produced two very closely matched biomass estimates. A third annual survey known as the pelagic pre-recruit survey initially aimed at predicting forthcoming anchovy recruitment strength has been discontinued. A large amount of environmental data are gathered during fishery independence surveys. Parasite data have recently been collected to assist with stock differentiation efforts for the sardine stock.

Fisheries dependent data collected from the trawling fishery include catches, catch per unit effort, catch-at-length and age-length keys, as well as observer data and positional data from VMS, the last mentioned being used primarily to monitor adherence to closed area restrictions. Observer coverage is at a relatively low level at the present time. Elsewhere in this chapter it is noted that ER (electronic reporting) approaches have been adopted by certain companies within the trawling fishery, but in these cases reporting is internal to the company, for purposes of fleet management. For demersal resources annual trawl surveys, which were initiated in 1984, are conducted. These provide an abundance index for a range of demersal species but the survey design has been optimized for hakes. These surveys were at one time run four times per year, but the number of annual surveys is presently down to two, due to operational problems with the FRV, the Africana (discussed elsewhere in this chapter) and also because not all surveys are deemed to be necessary for scientific purposes. Surveys provide environmental data and biological data for selected species. Recently the importance of the collection of stomach content data has increased. Hakes exhibit both cannibalism and inter species predation, and stock assessments are presently under development that model this feature of hake dynamics, requiring the availability of information on diet and daily food rations.

6.3.2 Funding limitations

Funding for the provision of "fisheries services" in South Africa has been severely curtailed in recent years. Cuts to observer programmes and staffing levels for government employed fisheries scientists has occurred. A number of management innovations have occurred which may provide some lessons and insights for the Australian situation.

6.3.3 Use of management procedures (OMPS)

In South Africa the following resources are being managed by means of management procedures, termed OMPs (operational management procedures):

- Hake fishery (this is an MSC certified fishery)
- West Coast rock lobster
- South Coast rock lobster
- Small pelagic fishery for anchovy and pilchard
- Horse mackerel

Particularly in the first of these, the hake fishery, curtailment of surveys or the introduction of MPAs or the non-availability of ageing data, is being evaluated in the context of the OMP methodology (i.e. a formal MSE / MP approach as per the terminology used elsewhere in this document). The general approach that has been followed in one or two instances has been to estimate the impact that the change or a proposed change in "fisheries services" (mainly a reduction in "research services") has on the long term catch that can be derived from the resource **on an equivalent risk basis**. This requires that the measure of biological risk is defined mathematically, and then the calculation of the forfeited catch implied by a reduction in "research services" can be calculated. This has at times produced surprising estimates of impact. For example, the impact of an MPA on the CPUE time series for the hake fishery was estimated at 10s of millions of AU$. This was because the MPA would effectively "break" the continuity of the CPUE time series, requiring the estimation of an additional catchability parameter in the assessment model, with feed through effects into management via the OMP.

One of the important motivations for the introduction of OMPs into the South African fisheries management context is that it will lead to a reduction in the amount of scientific deliberations. This is an appealing idea. The OMP is used for TAC calculations for each year, and every four years the OMP is revised. The application of the OMP is indeed far less time consuming than the traditional TAC deliberations that took place previously. However, the revision of the OMP each year must start early in year 3, and stretches through to Q4 of year 4, a period of at least 18 months of sometimes intense deliberations. The degree of intensity because important issues associated with the stock assessment must be addressed and resolved in short order, and because of the long term commitments that stakeholders are being required to make. It is thus moot whether the overall effort expenditure to run a fishery on an OMP basis is less than using a more traditional annual assessment based approach.

6.3.4 Species identification and catch estimation disaggregation in the hake fishery

The South African hake resource actually comprises two different species, *M. paradoxus* and *M. capensis*. The management system models these two stock separately. There is thus a need for reliable estimates of the catch per species on a tow or day by day basis for each vessel in the fleet, going back through the history of the fishery. Although government has at times made pronouncements that these estimates would be provided by real time at sea estimates, the costs involved are clearly too great. As a result species splitting of catches at sea is carried out retrospectively using a model built up from actual species data from demersal trawl surveys. The model is based on the depth of fishing, size of fish, the latitude and longitude and the fishing season itself. This model is checked from time to time against observer data, where these observer data comprise historic data from government funded observers (OROP), and latterly by industry funded observers (SADSTIA). This formulaic approach seems to work adequately, but has not been extended to other species compositions of the trawl catch. Development and maintenance of this model is funded by the industry and outsourced to independent service providers (see e.g. OLRAC SPS, 2012; Gaylard and Bergh, 2009).

6.3.5 Benthic research

The following excerpt from Benthic (2016) gives an idea of approaches being taken in South Africa to address issues that have come up about the potential impact of trawling on the sea bottom, a particular priority with the MSC certification of the hake fishery:

"A pioneering experiment being conducted in the Atlantic Ocean 100 nautical miles off the west coast of South Africa will tell marine researchers from the University of Cape Town (UCT) how long the seabed and its ecosystem takes to recover after hake trawling operations.

The Benthic Trawl Experiment is a joint research project between UCT, the South African Deep Sea Trawl Industry Association, the South African Environmental Observation Network (Saeon), and the Department of Agriculture, Forestry and Fisheries. It's the first in a series of experimental surveys of the impact of bottom trawling on the benthic communities - organisms that live in or on the seafloor - of the outer shelf of South Africa's west coast, says Associate Professor Colin Attwood, the chief scientist on the project. These will be conducted annually, though Attwood says it will take longer than the allotted four years for previously trawled lanes to bounce back. Saeon's Lara Atkinson, who is managing the project, says:

"We have been planning for a long time to get this experiment under way, and we're very excited about this opportunity to be able to monitor for any changes in the benthic communities in the areas where trawling has stopped."

The researchers have established a 6-by-15 nautical mile block within one of the fisheries' commercial blocks, and divided this into five lanes, two of which will remain open to trawling. The remaining three will be closed over the project's lifespan.

Data recovered during repeated surveys over this time will give researchers a clearer idea of recovery among seafloor species - and of the ocean floor itself, which becomes churned up by metal trawl "doors" (some weighing up to 10 tons) angled to hold open the net mouth as it is pulled along. A towed camera and a Van Veen grab (instrumentation used to collect sediment) will be used to sample benthic epi-fauna and in-fauna respectively."

6.3.6 EAF: Ecosystem Approaches to Fisheries Management

As a signatory nation to the 2002 World Summit on Sustainable Development (WSSD), South Africa is committed to develop and implement an Ecosystem Approach to Fisheries (EAF) management. EAF is based on two main principles. The first relates to maintaining and enhancing the ecosystem health as a whole and the second refers to balancing diverse societal needs and values. A workshop was convened in Cape Town in December 2002 to introduce and examine the options for implementing an EAF. Several modelling tools that rely on data collected through the monitoring programmes summarized in Hutchings et al (2009) are potentially useful for an EAF and it was recommended that an EAF be implemented in South Africa as an incremental procedure with immediate effect.

In mid-2003, a dedicated EAF Task Group (now functioning as a Scientific Working Group) was established by MCM (now DAFF). In addition to this national initiative, a regional (South Africa, Namibia and Angola) EAF project began in 2004, under the auspices of the Benguela Current Large Marine Ecosystem (BCLME, see website www.bclme.org), to investigate the feasibility of EAF management in the BCLME region through examining the existing issues, problems and needs related to EAF.

A further contribution towards EAF was an initiative to carry out Ecological Risk Assessments of South African marine resources. These were based on a methodology developed by Fletcher et al. 2002 and refined for local use (Nel et al. 2007, Paterson and Petersen 2010). To date ten ERAs have been conducted in southern Africa: six in South Africa and four in Namibia. On average 77 issues per fishery were raised at each ERA workshop (range 54 – 96). Despite the very different nature of the fisheries for which these assessments have been conducted and the diverse array of stakeholders that participated in these workshops, there was a high degree of concurrence in the issues raised between fisheries. Nel et al. [7] identified crosscutting issues among the initial eight ERAs, from which they distilled a checklist of 22 general management objectives and indicators. This checklist was further synthesized into ten generic (i.e. non fishery sector specific) objectives for implementing an EAF in southern Africa.

Despite the initiatives documented above, EAF remains a controversial topic for local fisheries management. Detractors are quick to point out that EAF has had scant impact on real fisheries management decisions anywhere in the world while proponents point out that this issue is here to stay and that the move to real EAF is inevitable.

6.3.7 Seabird - fishery conflict issues

Trawling-seabird interactions: Maree et al (2014) documents a successful outcome from the application of TORI lines in the local trawling industry. In 2004/2005, an estimated 9300 seabirds of which 7200 were albatrosses were killed annually through cable strikes in the South African deep-water hake trawl fishery. When comparing these figures to data from 2006 to 2010, when vessels used a single measure (bird-scaring lines) to reduce seabird mortality resulted in a 73–95% lower mortality in the winter/discard strata, a reduction in mean albatross deaths of > 95%. Bird-scaring lines cost < US$200 each in South Africa, a trivial expense per vessel for a measure that reduces fatal interactions with threatened seabirds so effectively. As a result the use of TORI lines is now a permit regulation in the South African trawling industry.

Pelagic purse seine - penguin interactions: An assessment of the feasibility of experimentally determining the impact of pelagic purse seine fishing on penguin population dynamics was initiated by the Department of Agriculture, Forestry and Fishing of South African in 2008. This feasibility study involved periodically closing an area within a 20 km radius of each of four important penguin breeding colonies to fishing, with different combinations of opening and closure applied over a number of years. One of the intended outcomes of the feasibility study was to determine the statistical power of analyses of the resultant data for quantifying the impact of pelagic fishing on penguins - prior to embarking on a long-term experiment. This work is still ongoing. Recently an assessment of the economic impact of these closures on the purse seine fishery was carried out (Bergh et al, 2015).

6.3.8 Use of PUCL to manage important retained bycatch species in the offshore trawl fishery

Although there are a number of retained bycatch species in the offshore trawl fishery (hake is dominant, comprising some 90% of catches), only horse mackerel and hake are subject to TACs and individual quotas. Participants in the management of the resource are well aware of the complexities that would arise should all retained bycatch species be managed by TACs and IQs, and there is considerable reluctance to introduce these measures. Instead, for stocks such as monkfish and kingklip, precautionary upper catch limits (PUCLs) are being set, and government and industry monitor catches and try to achieve consensus within the industry to take measures to ensure that catches do not exceed the PUCL. Since 2006 this process has been greatly assisted by the introduction of effort controls as a secondary control measure in the offshore trawl sector. Previously it was possible for vessels to remain at sea fishing against a potentially small hake quota, but high-grading for bycatch, causing considerable damage to the hake stock and to the targeted bycatch stocks.

6.3.9 FMAs and the kingklip box

A joint initiative by government and industry to limit kingklip catches was the creation of an FMA known as the kingklip box, a measure to protect the resource in the so-called kingklip box between September and November each year. Because kingklip are mainly resident on rocky terrain inaccessible to conventional trawling, only small volumes are consistently caught throughout the year except for a window period during late August, September and October. The fish congregate at this time largely around the 400 metre depth contour on the Chalk Line Grounds — almost certainly to spawn. The kingklip box closure limits the impact on the kingklip resource at this time of the year (see below).

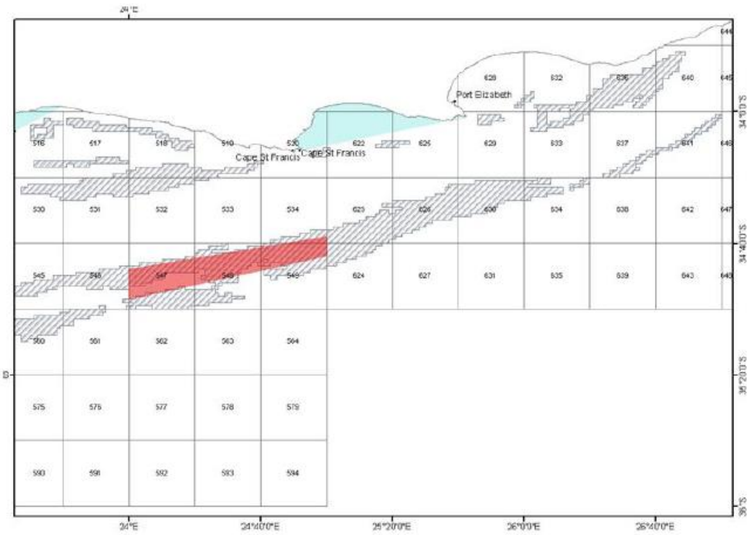


Figure 6-1: Kingklip closed area established off Cape St Francis (shaded red) to protect spawning aggregations from trawling between September and November each year.

6.3.10 Stock assessment prioritization

The Demersal Working Group regularly discusses and updates priorities for stock assessment work, but there is no formal procedure or scoring system that is used for in the development of these priorities. The result has in recent years been the following general workplan w.r.t. stock assessments:

- For stocks which are managed by OMPs, detailed and frequently substantially revised stock assessments are carried out every four years during the revision of OMPs. This revision process involves a period of work and research of typically (for hakes) 18 months, during which substantive new stock assessment work is carried out.
- In all years, for hakes, the most recent stock assessment model is run with updated data as available.
- For retained and important bycatch species in the offshore trawl sector, detailed stock assessments are run far less frequently. In some cases short cut methods are employed - the

most common technique has been the replacement yield approach using catch rate and/or demersal abundance indices as inputs (in addition to annual catches).

6.3.11 *Industry self-sampling programs, and industry funded research*

In a number of instances, often associated with new and/or novel management proposals, the costs and functions associated with the allied research services have been assumed by the relevant sector of the fishing industry. A recent example has been a 6 year long investigation by the industry into the merits of the female in-berry regulation in the South Coast rock lobster fishery. This has involved launching a multi-year self-sampling program to track the spatio-temporal patterns of berried females, running a trap survey in a previously unfished area, additional field studies and extensive research services in the area of data analysis and report writing.

Clearly where there is an advantage to the industry in the outcome, there will be an incentive to provide funding.

Another example is a recent exercise by the small pelagic fishery to estimate the economic impact on the fishery of the creation of closed areas around penguin breeding islands.

There are numerous example of industry funded research in the offshore trawling sector, which has funded research at its own behest to fulfill client action plans committed to the MSC certification process. Topics have included the development of by-catch management plans, new stock assessment approaches, research into the impact of trawling on the benthos, and the establishment of a trawl footprint (see elsewhere).

6.3.12 *Cost recovery and user pays principle*

Levies are paid by the industry at a tariff which is calculated on the weight of fish landed. The amounts involved are in the order of 1 percent of the value of the catch. These monies contribute to funding “fisheries services”.

Other than the above, additional cost recovery takes place without explicit planning, on a more or less ad hoc basis. There are a number of service providers who provide research services to industry associations. These include observer services and stock assessment services.

6.3.13 *Bycatch management - non TEP species*

Experimental Threshold (ET) programme to co-manage 10 bycatch species (see Bycatch (2015)):

The South African **inshore** trawl sector nominally targets hake (***Merluccius capensis*** and ***Merluccius paradoxus***) and Agulhas sole (***Austroglossus pectoralis***). The sector receives approximately 6% of the hake total allowable catch (TAC) and the entirety of the sole TAC. Due to a combination of unselective fishing gear (bottom otter trawl) and the bio-diverse fishing grounds of the Agulhas banks on the southern coast of South Africa, the fishery catches on average 40% bycatch in addition to the targets (hake and sole). Although over 100 bycatch species may be found in the catches from the inshore trawl sector, approximately 10 bycatch species and the target species represent 95% of the catch.

The inshore trawl sector, in conjunction with the larger offshore trawl sector, are Marine Stewardship Council (MSC) certified for their hake products. A condition of certification is to improve the research and management of bycatch species. The ET fishery conservation plan is a collaborative initiative between industry, government (South African Department of Agriculture, Forestry and Fisheries, “DAFF”), academic scientists from the University of Cape Town (UCT), and NGOs such as the Responsible Fisheries Alliance (RFA), MSC and the WWF.

The ET co-management programme is centred around annual catch limits for 10 bycatch species. The industry body will distribute these limits among rights holders annually pursuant to a formula developed by University of Cape Town scientists that considers each right holder’s target species quotas and historical performance of bycatch landings over a limited period. The industry body will facilitate within-season clearing or reconciling of ET catches among rights holders and encourage members to avoid exceeding limits. Should limits be exceeded, DAFF will take action to reduce further catches by restricting the entire fleet (rather than individual right holders). Action may include temporal or spatial closures of fishing grounds and/or roll-over provisions among other options. The system will be tested (and modified as required) during a pilot phase beginning in 2015. The intention is to fully implement the system at the start of the next round of Fishing Rights Allocations for the inshore trawl sector, once its usability has been established.

6.3.14 Data capture services and the management of the central fisheries database

In South Africa a reduction in funding for data capture services and IT management has been experienced. Many problems arose with the change over from a legacy database system to a new system. An important lesson here is the need for the fisheries management authority to maintain an iron rule over any IT projects that tamper with base data critical for management, supported of course by effective back-up systems using historical software that is not defunct. If the present situation is allowed to develop much beyond present levels it could have serious implications for fisheries management. This situation is being manage by focusing resources at critical data which is required to either revise OMPs or to run OMP formulae to calculate annual TACs. Other less critical data capture functions, such as the capture of hake stomach content data, which are not directly consumed by the OMP process, is given a secondary priority. At times industry has stepped in to fund additional data capture activity when there is a shortfall in data capturing resources.

In general it is appreciated by both government and industry that modern technology offers a way to reduce many of the costs involved in the traditional paper based logbook system, using electronic logbooks. Industry have at their own initiative launched a few of these programs (two of the largest operators in the hake trawl fishery, the South Coast rock lobster industry). These are not yet fully integrated with government databases, and there are many bureaucratic obstacles to getting these to the point where the possible cost savings on the government side are realized.

6.3.15 Availability of ageing data, catch-at-age for commercial vessels and surveys

This has been a particular issue for the hake fishery where for many years there was a serious backlog in the production of ageing data from otoliths gathered in the commercial fishery and in surveys. As a result this meant that the stock assessments for hakes, which used age production models, had little recent age data. To some extent this spurred on the development of an age-length-gender-species disaggregated assessment models which are able to utilize recent size structure data despite the absence of ageing data. Although this is a second best situation, it is better than not using the available size structure information. These assessment model innovations have made it possible to use a broader range of ancilliary data than was previously possible. For example, the gender disaggregation of the model makes it possible to reflect sexual dimorphism in life history strategy

For many years while there were ageing backlogs, industry toyed with the idea of outsourcing and funding ageing services, but recently the backlog has been reduced.

6.3.16 Assessments

6.3.16.1 Frequency of annual surveys, role of surveys, relative role of CPUE data

The main surveys carried out in South Africa as a component of “research services” are

16. Demersal trawl surveys which are designed primarily for input into management advice on hakes, but which serve a range of other demersal species management.
17. Hydroacoustic surveys of the abundance of small scale pelagics.

Focussing on (1), the demersal surveys are carried out using a government run research vessel, the Africana. There are at least two demersal surveys per year, each comprising about 90 trawls. In recent years the Africana has not been available for surveys and the surveys have been carried out using a commercial vessel on charter, the Andromeda. For the hydro-acoustic surveys, a commercial vessel, the Compass, has been calibrated and used, also on charter. This has spurred a debate in scientific and management circles about the necessity of the costs of upkeep of a dedicated research vessel. The general consensus in the industry is that commercial vessels can be used, and that the costs of the Africana are prohibitive and avoidable. However, a major mitigating factor that has arisen is that although the charter vessel may use the same research gear as the dedicated research vessel, this does not address a difference in catchability that arises due to the so-called vessel effect. In general therefore scientists are pushing for any change of survey vessel (or gear, see later) to be subject to extremely expensive calibration surveys where vessel catch rates and selectivities are compared despite the only difference being vessel. This raises the problem of whether, for e.g., the Andromeda will always be available for survey charters, and whether if another vessel has to be used, similar calibrations are required. The industry are arguing for a pragmatic approach to this, claiming that the dedicated Africana has been operated in non-standard ways in certain years, but been treated as the same vessel, so that pragmatically by the same token the relative catchability between the Andromeda and the Africana could be kept at 1.00. This debate is somewhat controversial and ongoing. Large funding issues are involved.

The hydro-acoustic problem is less of a concern because vessel calibration for hydroacoutics is a much cheaper exercise than for demersal trawls.

Related problems of calibration have arisen because the survey gear used by the Africana was changed, requiring additional expensive calibration trials to be run. Many scientists and industry representatives are re-assessing the wisdom of introducing new survey gear because the inter-calibration problem has rolled on endlessly. Advice for other countries in this regard would be to never change the survey gear, if at all possible.

A recent Marine Policy paper (Marine Policy 58 (2015) 108–115) notes that "fishery-independent monitoring is invariably more costly than fishery-dependent monitoring but is justified on the basis of the value of the data for effective management, or is viewed as the only valid approach for setting Total Allowable Catches (TAC). The benefits of fisheries independent surveys was assessed using a simulation approach. The results showed that TACs that can be awarded when fisheries independent survey data are available are up to 20% greater than the model-predicted estimates using CPUE data alone. Including both independent fishery surveys returned a positive net present value over a 20 year timeframe even when randomly varying biomass, accounting for increasing survey costs, lower gross margins, and lower lobster prices."

6.3.16.2 Data poor management approaches

Although South African scientists are involved in various initiatives aimed at the development of management and assessment approaches for data poor fisheries (e.g. Geromont and Butterworth, 2015), this approach is not part of a formal triage process for South African stock assessment work. Rather there is an ongoing debate and discussion which takes place at DSWG level (Demersal Scientific Working Group) and a consensus decision is made about the appropriate approach and timing for the assessment of particular stocks. For certain stocks, if a full age structured assessment is too time consuming given resources available in a particular year, then the assessment and management is based instead on a replacement yield approach using - typically the resource abundance estimate from demersal surveys is used as the biomass index in those calculations.

6.3.17 Management

6.3.17.1 Effort controls

With the exception of the squid jigging fishery in the Eastern Cape, most fisheries in South Africa are managed by means of output controls, either by means of explicit TACs and individual quotas, or in the case of by-catch in the hake trawl fishery, by a PUCL (Precautionary Upper Catch Limit).

However, the industry (with government support) has initiated input controls, specifically effort controls, in the South Coast rock lobster fishery and in the hake trawl fishery, and is busy formulating proposals for effort controls for the West Coast rock lobster fishery.

Some important features of these initiatives are:

1. The effort controls are intended to complement and not replace the existing and traditional output controls based on TACs, IQs and PUCLs.
2. Effort controls are a secondary control measure, designed so that they will typically become an active constraint in 1 in 20 years only (to cite a typical design threshold used for the system in place for the South Coast rock lobster fishery).
3. Effort controls have been initiated by the industry and have therefore been designed on a consensus basis by the applicable fishing industry association.
4. Effort controls are allocated to fishing rights holders as seadays, or similar measure (for hake trawling, effectively horsepower x seadays) on a similar rights splitting basis as are TACs and quotas.

On reflection, effort, when in concert with TAC / quota, is a cost effective way of managing biological risks. They are cost effective, because, provided the definition of effort is sensible, easy to understand, and easy to measure, they are easy to control and monitor. The measure used in the South Coast rock lobster fishing is a seaday measure, which is easy to calculate as the number of days out of port. It is also easy to cross check this control measure using VMS data. A related approach is used in the offshore trawl sector, and some specialized software has been developed to facilitate the creation of fishing plans on a vessel by vessel basis - the main operative measure of effort for offshore trawling in South Africa is horse power seaday.

An area which has barely been touched on in the South African situation is the risk mitigation aspect of effort controls. It is possible that some of this risk mitigation potential could be converted into savings in the costs of providing "fisheries services", using an equivalent risk argument, backed up by the necessary MSE's, as mentioned earlier in this chapter. The simulations testing of the value of effort controls in tandem with output controls is a potentially valuable adjunct in marine fisheries management systems.

6.3.17.2 MPAs, Gear, Closed Seasons, FMAs

MPAs, Gear restrictions, Season Limitations and Fisheries Management Area all offer potential risk mitigation for fisheries management. In circumstances where a user pays principle applies or there is some other costs recovery system in place, the opportunity to offset any additional risks due to a reduction in fisheries services against risk mitigation by the introduction of additional measures should most likely be explored.

In South Africa **MPAs** are gazetted no-take zones. Their utility for risk mitigation in fisheries management is highly contentious both in South Africa and internationally (where there is an active debate taking place in numerous published articles). At the extreme of either completely sedentary or highly migratory resources the mechanism whereby MPAs deliver a positive effect for sustainable yield are not well understood, or do not derive from the paradigm of existing models used for fisheries management. This debate is unresolved in the South African context, and proposals for the creation of offshore MPAs are now being motivated on the grounds of biodiversity conservation and not fisheries benefits.

Closed Seasons / Input Controlled Fisheries: Closed seasons in fisheries management are used in the management of effort in the squid jigging fishery, and to control the impact on the West Coast rock lobster resource during the female in-berry period. In the case of the squid jigging fishery managers have for many years been concerned about the management of effort in the fishery, since data suggests that a large number of the 136 vessels in the fishery utilise far fewer than the available seadays. The effort that these vessels could use is known as latent effort. Without any additional closed seasons the full utilisation of this latent effort could theoretically double the amount of effort used, although the reality of trip turnaround times puts constraints on the maximum the effort can reach at less than double, but nevertheless above a safe effort level. Two approaches to reduce effort were considered:

- **Reduce crew permits only:**
- **Introduce an additional 4 month closed season, reduce crew permits slightly:**

The proponents of the effort reduction options in the previous paragraph also proposed that effort permitted per vessel be capped at each vessel's historic effort level, suggesting that this could be monitored by VMS. The reality of latent effort is however strongly contested by industry representatives, they suggest that the data are either incorrect and/or that the majority of vessels are already turning trips around at close to the maximum level. In contradiction to this view, there were no significant reductions in fishing effort levels when additional closed seasons were declared in the past.

6.3.18 Big data and electronic technology, a reduction in the frequency of surveys (note DG MARE)

One of the most expensive components of fisheries services are fishery independent surveys. We mentioned previously that it may be possible to contain these costs by the use of charter vessels (with the added caveat about the costs of calibration surveys). A more direct approach however is to reduce the frequency of surveys. Before considering this, it is necessary to understand why fisheries independent surveys are regarded as such an important "fisheries service". One of the most important immediate outputs of the fishery independent survey is an index of abundance. This is particularly important in fisheries where effort creep is a concern, as in trawl fisheries. Strategically therefore these surveys are seen as an essential component of the management of many fish stocks. And particular stocks where gear innovations are taking place, as is typical in trawl fisheries, especially where these are economically marginal and/or high cost, which is usually the case. In South Africa fisheries independent surveys take place for demersal resources, small pelagics, and for West Coast rock lobster. It has been taken as a given in South Africa that these surveys should be carried out annually. In the case of demersal resources and small pelagics the surveys are in fact biannual, while a single annual FIMS (Fisheries Independent Monitoring Survey) occurs for the West Coast rock lobster resource. However, because of the unreliable availability of the dedicated research vessel the Africana, and despite the use of a commercial vessel on a charter basis, there have been instances where a survey has been missed. As a result, simulation testing of the OMP has included sensitivity tests to establish whether the formula is robust to instances of missed surveys. In general the robustness of the formula to an occasional data gap has been confirmed. This illustrates the value of the OMP methodology to guide decisions about a curtailment of research services.

We return to the problem of effort creep. There are numerous published examples of levels of creep that are in the order of 2% per annum. These have in the past been proposed as a possible indication of the extent of creep in the South Africa trawl fishery. The industry has however contended that this is not possible. Again, in this case, OMP robustness to creep has been checked and verified. It is significant of course that the survey indices are part of the OMP formula and this is most likely one of the reasons why the OMP is robust to this effect (of course assessing the performance of an OMP to a sensitivity test involves some subjectivity).

In the South African context however, a deliberate and planned reduction in the frequency of surveys is likely to lead to a modification of the OMP formula for the management of hakes. Arguments will be led that an equivalent risk approach should be taken, and in order to achieve this, failing any other risk mitigation, the average TAC will have to be reduced. This amounts to transferring the burden for cost savings on fisheries services to the fishing industry.

6.3.19 Eco labelling

MSC certification has had a considerable impact on the management of the South African hake resource with respect to governance, the promotion of sustainable fisheries management practice, and the application of ecosystem-based management approaches. This new paradigm has resulted in considerable improvements in the management process that were absent in the decades preceding certification. Underlying all of this is the acknowledgment that MSC certification brings substantial economic benefit to the hake trawling industry, to processors and traders, and consequently also generates employment opportunities. A recent economic study on the value of MSC certification for the offshore trawling industry, Lallemand et al (2016), will appear in a special edition of "Fisheries Research" focusing on eco-labelling. This paper estimates that 35% of the total value of the fishery is due to MSC certification and would be lost if certification was lost. The reality of this estimate has significantly altered the nature of fisheries management for the South African bottom trawling sector, effectively directing research resources and fisheries services in such a way that maximizes the upkeep of the MSC certification. This has brought into focus issues that fall under the three pillars of the MSC certification process: Governance, Sustainability and Environment. This change has taken place since certification in 2004 and it has made the industry a very willing and cooperative partner in the provision and funding of research services.

At the present time there are no other MSC certified fisheries within South African waters. Factors that are inhibiting the uptake of certification are:

- The cost of certification, considerable in a South African context
- The open ended nature of the MSC - industry relationship, given that an ongoing critique of fisheries management by NGO and other IAPs can lead to even greater costs and measures to maintain certification
- The perceived fallout of losing certification
- There is no requirement for MSC certification in the relevant export market for that fishery.

As such it seems likely that the fit of MSC certification, and the kind of management reforms and user paying motivation is likely to have to be assessed on a case by case basis. It is nevertheless likely that consumer pressure via eco-labeling bodies and thus the influence of eco-labelling bodies such as the MSC will grow further over time. The opportunities that this creates for the management authority in terms of cost cutting needs to be recognized.

7 Synthesis and recommendations for research, monitoring and assessment

This review has sourced a diversity of, but not an exhaustive set of all available information about the practices and developments in the provision of fisheries services for research, monitoring and assessment, in the USA, Canada, South African and New Zealand.

The most expensive aspects of fisheries services, excluding MCS and enforcement, are at sea observer programmes, fishery independent surveys and stock assessments combined with the formulation of management approaches and management advice, **as well as** growing public pressure for demonstrable sustainability and ecosystem approaches to fisheries management.

The last mentioned (EAF) is leading to an increase in the scope of fisheries services, particularly in multispecies trawl and long-line fisheries.

7.1 Stock assessments and management services - towards cost efficiencies

The USA has over 400 species and/or stocks under management, New Zealand over 600. All are potentially separate entities that have a need for fisheries services. All may in terms of existing legislation require the determination of TACs and eventually IQs (New Zealand) or catch shares (USA). It seems that in New Zealand the response has been to leave hundreds of TACs unchanged over many years, and to focus attention and fisheries services on the most valuable stocks. In the USA a much more explicit prioritisation of fisheries services for stock assessment is taking place. This is a method of directing the available resources for stock assessments in the most "profitable" manner, and once adopted is likely to avoid wasteful application of stock assessment expertise. In particular this framework allows for the designation of resources for a first time assessment. This approach has merit, particularly if there is widespread stakeholder involvement in its development and adoption, since it is a structure that can be referred to if questions are raised about why certain stock assessments are done and not others, and it is a structure that can be used, saving considerable time in the planning and administration of stock assessments. NOAA has recommended that this system be applied at a regional level in the USA.

Although not a topic reviewed in the main body of the document, it is relevant to fisheries service costs that a number of RFMOs (IOTC, WCPFC, CCAMLLR) are pursuing "canned" stock assessments based on the application of easy to use packages such as Stock Synthesis, Multifan, Casal and others. These methods offer a less expensive route to performing age structured stock assessments compared to approaches where stock assessment models are developed ab initio using programming templates like ADMB and TMB. Such options should be explored since these canned approach do offer the capability to include a variety of data types typical in fisheries. And they can be implemented by persons who are not both computer coding experts and assessment experts, but may be fisheries biologists who have an aptitude for involvement in stock assessments. This would be an option for data moderate to data rich fisheries that do not number above 10 or 20 stocks. It would also require, given a stock assessment, the determination of management advice, but it is felt that these canned systems provide sufficient functionality for this.

We believe that a different approach should be used for data poor fisheries that number in the many tens or even hundreds. In these cases the best approaches, consistent with the best international advice and precedent, are shortcut methods which provide a direct management recommendation, i.e. management procedures, without an intervening stock assessment analysis, and which have been validated by use of the MSE approach. This recommendation is being made even though our review found that MPs consistent with the IWC definition are non-existent in the US context, and only one instance is on record for New Zealand. Their application is however well established in South Africa. Nevertheless the available documentation and literature is unequivocal in its recommendations about this path. We make a distinction between MSE / MPs for data rich versus data poor fisheries, and recommend that the expenditure of resources in developing new MPs and / or refining existing MPs (as in e.g. Knuckey et al, 2008) for data poor fisheries is worth pursuing further. It seems that at least two options arise, one is to develop MPs that are applicable to a basket of species or stocks that share common biological and data characteristics (the "basket" approach), thereby achieving an economy of scale with respect to the expenditure of technical expertise, while another is to develop canned MSE / MP systems (the "canned MSE" approach) which can quickly update MPs for a specific data poor stock, and that could then develop hundreds of MPs fairly cheaply.

There is one reservation about the "basket" approach. In the above, stock assessment services are themselves viewed as a cost, and cost reductions are under consideration. However the terms of reference of this study are inter alia to explore cost efficiencies in relation to the intensity and frequency of fisheries and research services. Thus there is a requirement that, in making recommendations about fisheries service provision, the capability to give advice about trade-offs between fisheries service costs / fisheries management risk / fisheries is developed. And the recommendation on this issue is again that only the MSE / MP approach has the potential to provide this capability, since the empirical approaches that we reviewed were not successful, and elsewhere in the world (South Africa for example) MSE / MP is the dominant approach for exploring such trade-offs. Therefore it seems likely, given that the need to right size the cost of fisheries services will be ongoing, the MSE / MP approach would have to incorporate the ability to weigh up, for example, the merits of different survey frequencies and other aspects of fisheries service costs. The question is whether the "basket" approach will be flexible enough to allow this ongoing interrogation or whether the "canned MSE" approach is better. This depends on whether the trade-off issue needs regular review (every year) or only fairly infrequently (every 5 to 10 years).

7.2 Fisheries independent surveys

All literature available to this study emphasizes the importance and value of fisheries independent surveys.

The reviews in all countries support a very positive assessment of the benefits that are derived from Fisheries Independent Surveys (FIS). The examples from the USA reviewed here show the planning that went in at a federal level to estimate the quantity of FIS needed, the best design for the FRVs required to meet these requirements, and the recognition of the need for a degree of chartered vessel and university vessel input to complement the FRV capability. This reflects an acknowledgement of the importance of FIS work, and a very serious commitment to it. The cost benefits of different levels of FIS frequency are not clearly expressed in the USA, although these seem to be at least annual for important stocks. The example of South Africa is to highlight the value of the MSE / MP approach to quantify the cost benefit trade-off of dropping surveys from the annual schedule.

In the USA the investment in this capability is substantial. NOAA supplements the use of dedicated FRVs with charters, and these charters include the use of commercial vessels, amongst other sources. These charters make up in the order of 50% of the requirement. FRVs are very expensive to build and maintain, and run. There are many opportunities where commercial charters can be used, especially where the actual vessel that is used for a survey, whether an FRV or a commercial vessel, is not critical. This is the case with certain types of fishing gear, such as fishing traps (pots). The literature does not however support such a view in the case of trawl fisheries, and trawl fishery independent surveys. Unfortunately the use of commercial charters in this case requires allied research to cross calibrate different vessels. These calibration surveys are extremely expensive to run, and so any use of commercial charters for trawl must weigh up either the costs of these calibration surveys, or the cost to the fishery of the additional risk aversion required to incorporate uncertain cross calibration factors between charter vessels. An ideal situation might be where a commercial charter is available over many years, nullifying the calibration problem.

For trawl fisheries there is the temptation to dispense with fisheries independent surveys, and rely solely on CPUE data. However, trawl technology is malleable in a way that traps and fixed gear are not, and therefore effort creep remains a problem, and the absence of FIS's would make is very difficult to achieve certification by a reputable eco-certifying agency such as the MSC. Costs savings in this area therefore need to explore, amongst other possible measures:

- Minimizing where possible the frequency of surveys
- The multi-functional application of FRVs.

7.2.1 Recommended frequency of surveys:

This review did not find a basis for providing generic advice on the recommended frequency of surveys. We note however that the methods for the prioritization of stock assessments in the USA include proposals to link the **frequency of stock assessments** to the average age of fish in the exploited stock, modified by the amount of recruitment variability - decreasing the interval by a specific amount for stocks with high levels of recruitment variability, or increasing them by a specified amount for stocks with low variability. This is an interesting idea and is based on a concept of how quickly things can change (or go wrong) between successive assessments, assumed to be faster for lower average ages of fish in the stock. There is potential to extend this idea to the frequency at which fisheries independent surveys are carried out. At this stage this is just an interesting concept which should be validated using an MSE / MP approach - should such a study confirm a rational basis for linking survey frequency to average age, a decision rule based on this could be a useful tool for planning fisheries independent surveys.

7.3 Electronic Monitoring

Monitoring by means of at-sea observers is an expensive exercise. For almost ten years now video based monitoring, or EM (Electronic monitoring) has been trialed in the USA, Canada, Australia and New Zealand. Studies have assessed the efficacy of this technology according to the same standards that at sea observers are measured. The results are equivocal and case and issue specific. A majority of these studies estimate and conclude that EM is cheaper than human observers.

Most studies report that the technology performs well as a compliance monitoring tool, but poorly at estimating discards and interactions with TEP species, or for gathering data that can be used in science and management. Some studies favour the application of the technology in a self-sampling situation where the EM technology is used as a means to audit the reliability of the self-sampling work. This gets around the review problem which is time consuming and hence expensive and may be a weak link in the system - a New Zealand study concluded that the review work should be domesticated (existing systems involve off site remote reviews) so that experts in local fauna could be enlisted to increase the reliability and detail of species identification achieved. The adoption of **the present generation of EM technology** in North America is extremely limited, non-existent in New Zealand (as far as documentation uncovered for this study) and much of the documentation available relates to many scores of pilot studies run to assess the usefulness of the technology. This in itself tells a story, and suggests that some caution be applied in its adoption.

Another issue is that, as with all technology, the pace of change and innovation is considerable. Other as yet untested technologies are coming onto the market. These include systems based on high or variable frequency high definition camera stills instead of video and they may offer a number of advantages in particular situations.

7.4 Electronic Reporting

ER offers cost savings compared to the regular paper logbook approach, and the uptake of this technology is widespread in certain countries and jurisdictions (for example the EU and Australia, but not to the same extent in the USA). Apart from cost savings, an advantage of this technology is the ability to access a far greater range of data than is feasible using paper logbooks, potentially giving access to “big data”. In addition the more sophisticated offerings in this suite of technology go beyond simple ER and include a shipboard data center which allows skippers and crew to accumulate all their fishing data over time and use it by with the help of historical reports, GIS views and other facilities, offering a service which the vessel skipper can use to achieve own efficiency enhancements. This is then an incentive which motivates further uptake of the technology and further cost savings.

The recommendations in this regard are uncontroversial and in favour of the adoption of ER technologies as soon as practically possible.

It is however strongly recommended that the central authority does not become a software developer, but rather that the authority (e.g. AFMA) issues data standards and certifies suppliers’ products as being consistent with these standards. There are many instances in which government departments have got involved in the actual funding and development of this technology and the costs incurred with such an approach can easily be demonstrated to have been literally orders of magnitude greater than sourcing commercial products which suppliers would be willing to customize for purpose. In addition, it is possible to test and trial the technology to verify its applicability.

7.5 Ecosystem approach to fisheries

It is clear that fisheries management authorities in all jurisdictions relevant to this review have been tasked with adopting an ecosystem approach to fisheries management, EAF, consistent with the undertakings that their governments have made at international level. It is however far less clear what exactly is meant by EAF, and even less clear how to achieve it.

The attempt to seriously pursue EAF has the potential to make demands on fisheries services that would dwarf the existing extent of these services.

It seems that in scientific circles there is still considerable controversy about EAF, and thi s stems from the single species view of stocks and their management, which is complex enough in itself, coupled with an appreciation of the complexity of the marine ecosystem. Simply put, EAF is outside the comfort zone of most quantitative fisheries scientists.

In South Africa the EAF approach has progressed up to the point that ERA's (ecological risk assessments) have been carried out for the major fisheries, using a method adapted from Fletcher et al (2002). These ERA's represent an inventory of the scope of issues that need to be considered with respect to governance, sustainability of fisheries, and broader environmental and ecological impacts. In some cases they also touch on socio-economic aspects. In addition some specific ecosystem level models have been developed, however none of these models have registered any impact at a management level. None of them pass any reasonable test for whether they represent a serious approach to EBM (Ecosystem based management). In some local scientific circles these are presented as the precursors of an eventual EBM, in other local scientific circles they are viewed as a pipe dream. Some scientists argue that the analogue of Heisenberg's Uncertainty principle in physics is applicable to marine ecosystems, i.e. that the sampling that would provide information about the state and dynamics of the system would significantly perturb the system away from its natural course , such that certain information is effectively unknowable. However, despite these protestations, it is undisputed that society at large wants EAF, and it is also clear that a lot of their tax money is paying for fisheries services, and so this issue will persist, and the scientific community and fisheries managers will, plainly speaking, have to find a way to respond effectively.

In the USA a workmanlike approach to incorporating EAF or EBFM (Ecosystem Based Fisheries Management) into FMPs (Fisheries Management Plans) was initiated by a policy and action framework summarized in Fluharty and Cyr (2001). A NOAA (2014) assessment of progress against those actions by each of the eight regional fisheries management councils shows only partial compliance with these actions, but nevertheless significant progress has been made. It is the view here that the USA approach provides a useful blueprint for how to advance EAF and how to assess progress, and it is recommended that this blueprint be cross checked with the Australian approach to see what gaps if any exist, and what could be useful transplanted across to the Australian situation. Although this was not researched in detail, we suspect that the conceptual and implementation debate around EAF which is very evident in South Africa exists in the USA, and may inhibit a more fundamental conversion of the standard single species approach to EBFM.

7.6 Other

7.6.1 Dual Input / Output Controls

Since this point may have been lost in the main body of this document, the experience in South African with the use of dual input / output controls is reiterated. In the way that these have been developed and implemented, i.e.

1 The effort controls are intended to complement and not replace the existing and traditional output controls based on TACs, IQs and PUCLs.
2 Effort controls are a secondary control measure, designed so that they will typically become an active constraint in 1 in 20 years only .
3 Effort controls have been initiated by the industry and have therefore been designed on a consensus basis
4 Effort controls are allocated to fishing rights holders as e.g. seadays pro rata to their IQ (catch share),

they have lead to very positive outcomes. Such controls are also consistent with FAO's code of conduct for responsible fisheries management.

There may be opportunities for dual input / output controls in the SESSSF, and we believe that in conjunction with an MSE / MP approach to management they could favourably alter the cost - risk - benefit frontier, and should be considered for implementation, where such benefits are evident or demonstrated by MSE research.

7.6.2 Streamlining procurement processes for fisheries services

A further issue that should not be lost are the innovations documented in New Zealand to align fisheries services more closely with the objectives of FMPs, and to streamline the process by which fisheries services are procured. This can be viewed as a BPM (business process management) revision, and in large commercial operations, improvements in BPM, if properly planned and implemented, are normally associated with large cost savings and efficiency improvements.

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Table 8-1. Extract from Wallis and Flaaten (2003) showing the costs associated with the provision of fisheries services, as well as total landings and values, for Australia, Canada, New Zealand, United States and OECD countries as a total.

	Research Costs (USD million)	Management costs (USD million)	Enforcement costs (USD million)	Total Fisheries Services Costs	Landed Value (USD million)	Management Costs / Landed Value (%)	Landings ('000 Tonnes)	Management costs / Landings (USD / Tonne)
Australia	9.5	19.45	...	28.95	259	11%	71	407.79
Canada	40.84	95.6	Included in management costs	136.44	1621	8%	894	152.63
New Zealand	11.9	15.2	13.22	40.32	475	8%	...	...
United States	95.44	165.73	400	661.17	3644	18%	4635	142.66
OECD Total	506.96	978.24	751.92	2237.12	38032	6%	33610	71.43

Table 8-2. Aggregate scores (unweighted) for marine resources management for 53 maritime countries from Adler and Pauly (2008) and Adler et al (2010).

Table 3. Aggregate scores (unweighted) for marine resources management for 53 maritime countries

Country	Aggregate Score	Country	Aggregate Score
New Zealand	5.5	Portugal	4.0
Peru	5.2	Latvia	3.9
Germany	5.2	Ukraine	3.9
Netherlands	5.1	Malaysia	3.9
USA	4.8	Philippines	3.9
South Africa	4.8	Morocco	3.9
Australia	4.8	Argentina	3.8
UK	4.8	Mexico	3.8
Sweden	4.6	China	3.7
Senegal	4.6	Turkey	3.6
Spain	4.5	Angola	3.6
Japan	4.5	Taiwan	3.6
Chile	4.4	Ghana	3.6
Namibia	4.4	Thailand	3.6
Canada	4.4	Indonesia	3.5
Ireland	4.4	Pakistan	3.4
France	4.4	Viet Nam	3.3
Denmark	4.4	Myanmar	3.3
Iceland	4.3	Yemen	3.3
South Korea	4.2	Sri Lanka	3.2
Poland	4.2	Iran	3.0
Norway	4.2	North Korea	2.8
Nigeria	4.1	Brazil	2.8
Russia	4.1	India	2.7
Egypt	4.0	Faeroes	2.7
Ecuador	4.0	Bangladesh	2.3
Italy	4.0	--	--

Table 8-3. Fisheries that are judged to be suitable for the implementation of EM / ER, from NMFS Alaska (2015).

Table 3.1. Summary of the existing monitoring tools currently implemented in the North Pacific. Catch share programs require a more intensive suite of monitoring tools for management and are therefore listed separately from the non-catch share programs. Green cells indicate fisheries where electronic technologies have already been implemented and regulated programs are in place. Fisheries where additional Electronic Reporting (ER) and Electronic Monitoring (EM) could potentially be suitable are noted; yellow cells indicate fisheries that have been identified as high priority for implementation and have initiatives underway. (Note: AFA = American Fisheries Act; BSAI= Bering Sea/Aleutian Islands; CP = catcher/processor; CV = catcher vessel; GOA = Gulf of Alaska; IFQ = Individual Fishing Quota; IERS=Interagency Electronic Reporting System; LOA = length overall of vessel)

Program Type	Fishery	Current Requirements									Additional ER Potentially Suitable?	Potential EM Application?
		ER for Landings &/or Production (IERS)	Paper logbook[2]	ER for logbook (elogbook in IERS)	ER for Observer data (Atlas)	Flow Scale	VMS	Video	Observer Coverage	2nd Observer		
Catch Share	BSAI pollock trawl CP & mothership (AFA)	Y	N	Y	Y	Y	Y	Y	100%	Y		
	BSAI non-pollock trawl CP (Amendment 80)	Y	N	Y	Y	Y	Y	Y	100%	Y		Y - video and/or flow scale to monitor deck sorted halibut PSC
	Central GOA Rockfish Trawl CP	Y	N	Y	Y	Y	Y	Y	100%	Y		
	BSAI Pacific cod Longline CP	Y	N	Y	Y	Y	Y	Y	100%	Y		
	BSAI rationalized crab CP	Y	Y	Few-voluntary	N	Y	Y	N	100% - not NMFS	N	Y- elogbook	
	BSAI pollock trawl CV (AFA)	Y	Y	Few-voluntary	Y/N[3]	n/a	Y	N	100%	N	Y- elogbook; Atlas	
	CGOA Rockfish Trawl CV	Y	Y	N	Y	n/a	Y	N	100%	N	Y- elogbook	Y-compliance monitoring & estimation of halibut PSC
	IFQ Sablefish CP	Y	Y	Few-voluntary	N	N	Y- AI only	N	100%	N	Y- elogbook	
	IFQ Halibut CP	Y	Y	Few-voluntary	N	N	Y- AI only	N	100%	N	Y- elogbook	
	IFQ Sablefish CV	Y	Y	N	N	n/a	Y- AI only	N	Partial	N	Y- elogbook	Y- video for catch estimation
	IFQ Halibut CV	Y	Y[4]	N	N	n/a	Y- AI only	N	Partial	N	Y- elogbook	Y- video for catch estimation
	IFQ Halibut & Sablefish <40' LOA CV	Y	Y[2]	N	N	n/a	Y- AI only	N	None	N		Y – video for catch estimation
Non-Catch Share	BSAI Turbot longline CP	Y	Y	N	N	N	Y	N	100%	N	Y- elogbook	
	GOA Trawl CP	Y	Y	N	N	N	Y	N	100%	N	Y- elogbook	
	GOA Longline CP	Y	Y	N	N	N	Y	N	100%	N	Y- elogbook	

[2] Paper logbooks are required by NMFS for vessels >60ft
[3] Electronic reporting software for observers, Atlas, is currently required for vessels >125' but some vessels <125' voluntarily use Atlas
[4] Paper logbooks are required by IPHC for vessels >26 ft fishing for halibut; vessels >60ft are also required to submit paper logbooks by NMFS and there is a shared IPHC-NMFS paper logbook.

Program Type	Fishery	Current Requirements									Additional ER Potentially Suitable?	Potential EM Application?
		ER for Landings &/or Production (IERS)	Paper logbook[2]	ER for logbook (elogbook in IERS)	ER for Observer data (Atlas)	Flow Scale	VMS	Video	Observer Coverage	2nd Observer		
Non-Catch Share	BSAI Pacific cod Trawl CV	Y	Y	N	N	n/a	Y	N	Partial; some vessels 100% voluntarily	N	Y- elogbook	
	GOA pollock Trawl CV	Y	Y	N	N	n/a	Y	N	Partial	N	Y- elogbook; tLandings for tenders; Atlas	Y- compliance monitoring of no discard
	GOA non-pollock Trawl CV	Y	Y	N	N	n/a	Y	N	Partial	N	Y- elogbook; tLandings for tenders; Atlas	Y-compliance monitoring & estimation of halibut PSC
	Pot CP	Y	Y	N	N	N	Y	N	100%	N	Y- elogbook	Y – video for catch estimation
	Longline & Pot >=40'LOA CV	Y	Y	N	N	n/a	Y	N	Partial	N	Y- elogbook; tLandings for tenders	Y – video for catch estimation & PSC monitoring
	Longline & Pot <40'LOA CV	Y	N	N	N	n/a	Y- AI only	N	None	N		Y – video for catch estimation & PSC monitoring
	Jig	Y	Y	N	N	n/a	Y- AI only	N	None	N		

Table 8-4. Loefflad et al (2014) ("Strategic Plan for Electronic Monitoring and Electronic Reporting in the North Pacific") - a summary of existing monitoring tools currently implemented in the North Pacific fisheries

		Monitoring Tools							
Program	**Fishery**	**Paper logbook [1]**	**E-logbook**	**Flow Scale**	**VMS**	**Video**	**Observer Coverage**	**2nd observer**	**ATLAS**
Catch Share	AFA CPs/motherships	N	Y	Y	Y	Y	100%	Y	Y
	BSAI Trawl CPs in H&G	Y	Y - voluntary	Y	Y	Y	100%	Y	Y
	CGOA Rockfish CP	N	Y	Y	Y	Y	100%	Y	Y
	BSAI P.cod Freezer Longliner	N	Y	Y	Y	Y	100%	Y	Y
	CR Crab CP	Y	N	Y	Y	N	100%- not NMFS	N	N
	AFA CVs	Y	few- voluntary	NA	Y	N	100%	N	Y[3]
	CGOA Rockfish CV	Y	N	NA	Y	N	100%	N	Y
	IFQ CP Sablefish	Y	N	N	Y -AI only	N	100%	N	N
	IFQ CP Halibut	Y	N	N	Y -AI only	N	100%	N	N
	IFQ CV Sablefish	Y	N	NA	Y -AI only	N	Partial	N	N
	IFQ CV Halibut [2]	Y [2]	N	NA	Y -AI only	N	Partial	N	N
	IFQ CV Halibut and Sablefish <40' LOV[3]	Y [2]	N	NA	Y -AI only	N	None	N	N
Non-Catch Share	BSAI CP Longline Turbot	Y	N	N	Y	N	100%	N	Y
	GOA CP Trawl	Y	Y- voluntary	N	Y	N	100%	N	Y
	GOA CP Longline	Y	Y voluntary	N	Y	N	100%	N	Y
	BSAI CV Trawl P.cod	Y	N	NA	Y	N	Y-voluntary	N	N
	GOA CV Trawl	Y	N	NA	Y	N	None	N	N
	GOA CV Longline	Y	N	NA	Y	N	None	N	N
	CP Pot	Y	N	N	Y	N	100%	N	Y
	CV Pot >=40' LOV	Y	N	NA	Y	N	Partial	N	N
	CV <40' LOV	N	N	NA	Y-AI only	N	None	N	N
	Jig	Y	N	NA	Y-AI only	N	None	N	N

1-Paper logbooks are required by NMFS for vessels >60ft

2-Paper logbooks are required by IPHC for vessels >26ft fishing for halibut; vessels >60ft are also required to submit paper logbooks by NMFS and there is a shared IPHC-NMFS paper logbook.

3-Length of Vessel (LOV)

4-Atlas is required for vessels over 125 LOV, but many vessels voluntarily use ATLAS

Table 8-5. Summary of the existing monitoring tools currently implemented in commercial fisheries of the Southeast Region.

Table 2. Summary of the existing monitoring tools currently implemented in *commercial fisheries* of the Southeast Region. Green cells indicate fisheries where electronic technologies have already been implemented and regulated programs are in place. Fisheries where additional Electronic Reporting (ER) and Electronic Monitoring (EM) could potentially be suitable are noted, and yellow cells indicate those fisheries that have been identified as the highest priority for implementation.

Region	Fishery	Current Requirements						Additional ER Potentially Suitable?	VMS or EM Potentially Suitable?
		Dealer Electronic Reporting	Paper logbooks/reports	Electronic Logbooks/reports	VMS	Video	Observers		
Caribbean	Reef Fish	N	Y	N	N	N	N	elogbook - pilot testing began in 2014	
	Queen Conch	N	Y	N	N	N	N		
	Spiny Lobster	N	Y	N	N	N	N		
	Corals and Reef Associated Plants and Invertebrates	Harvest and possession prohibited except with Federal permit for scientific research, exempted fishing, or exempted educational activity							
Gulf of Mexico	Reef Fish	Y	Y	N	Y	N	Y	elogbook - pilot testing in 2015	EM for protected resource interactions; reef fish bycatch
	Shrimp	N	N	Y	N	N	Y		
	Aquaculture	Y	N	Y	N	N	N	Proposed regulations	
	Red Drum	Y	N	N	N	N	N		
	Corals	N	Y	N	N	N	N		
Gulf of Mexico and South Atlantic	Coastal Migratory Pelagics	Y	Y	N	N	N	Y	elogbook - pilot testing in 2015	
	Spiny Lobster	Y	N	N	N	N	N		
South Atlantic	Snapper-Grouper	Y	Y	N	N	N	N	elogbook - pilot testing in 2015; wreckfish ITQ online system	Pingers or VMS in black sea bass pot fishery; EM for snapper-grouper bycatch
	Shrimp	Y - Rock Shrimp Only	N	N	Y - Rock Shrimp Only	N	N		EM for rock shrimp to link location specific catch/bycatch to VMS data
	Dolphin-Wahoo	Y	Y	N	N	N	N	elogbook - pilot testing in 2015	
	Golden Crab	Y	Y	N	N	N	N	elogbook	Pingers for crab traps
	Sargassum	N	N	N	N	N	Y		
	Corals	N	Y	N	N	N	N		

Table 8-6. Summary of the existing monitoring tools currently impemented in recreational fisheries in the Southeast Region of the USA.

Table 3. Summary of the existing monitoring tools currently implemented in *recreational fisheries* of the Southeast Region. Green cells indicate fisheries where electronic technologies have already been implemented and regulated programs are in place. Fisheries where additional Electronic Reporting (ER) and Electronic Monitoring (EM) could potentially be suitable are noted, and yellow cells indicate those fisheries that have been identified as the highest priority for implementation.

Region	Fishery	Current Requirements					Additional ER Potentially Suitable?	EM Potentially Suitable?
		Paper logbooks/reports	Electronic Logbooks	VMS	Video	Observers		
Caribbean	Reef Fish	N	N	N	N	N		
	Queen Conch	N	N	N	N	N		
	Spiny Lobster	N	N	N	N	N		
	Corals and Reef Associated Plants and Invertebrates	Harvest and possession of corals is prohibited except with Federal permit for scientific research, exempted fishing, or exempted educational activity; harvest of aquarium trade species allowed.						
Gulf of Mexico	Reef Fish	Y - Headboat only	Y - Headboat only	N	N	N	eLogbooks for charter; pilot testing electronic apps for private sector	VMS, if used in conjunction with electronic reporting or catch share program; pilot testing VMS in Headboat Collaborative
	Shrimp	Shrimp are not recreationally harvested in the Gulf of Mexico EEZ						
	Aquaculture	Proposed for commercial purposes only.						
	Red Drum	N	N	N	N	N		
	Corals	Live rock harvested for commercial purposes. Harvest and possession of corals prohibited except with Federal permit for scientific research, exempted fishing, or exempted educational activity.						
Gulf of Mexico and South Atlantic	Coastal Migratory Pelagics	Y - Headboat only	Y - Headboat only	N	N	N	eLogbooks for charter	
	Spiny Lobster	N	N	N	N	N		
South Atlantic	Snapper-Grouper	Y - Headboat only	Y - Headboat only	N	N	N	eLogbooks for charter	
	Shrimp	Shrimp are not recreationally harvested in the South Atlantic EEZ						
	Dolphin-Wahoo	Y - Headboat only	Y - Headboat only	N	N	N	eLogbooks for charter	
	Golden Crab	Golden crabs are not recreationally harvested in the South Atlantic EEZ						
	Sargassum	Sargassum is not recreationally harvested in the South Atlantic EEZ						
	Corals	Live rock harvested for commercial purposes. Harvest and possession of corals prohibited except with Federal permit for scientific research, exempted fishing, or exempted educational activity.						

Table 8-7. Table of attributes for assigning stock status for historical catch-only assessments (from Berson et al, 2011).

Table 4. Table of attributes for assigning stock status for historical catch-only assessments (from Berson et al 2011).

Overall scores are obtained by an unweighted average of the attributes for which scoring is possible, although alternative weighting schemes could also be considered. An initial assignment to a stock status category is: mean scores>2.5—heavily exploited; stocks with mean scores 1.5-2.5--moderately exploited; and stocks with mean scores<1.5--lightly exploited. When the attribute does not apply or is unknown it can be left unscored.

Attribute	Stock status		
	Lightly exploited (1)	**Moderately exploited (2)**	**Heavily exploited (3)**
Overall fishery exploitation based on assessed stocks	All known stocks are either moderately or lightly exploited. No overfished stocks	Most stocks are moderately exploited. No more than a few overfished stocks	Many stocks are overfished
Presence of natural or managed refugia	Less than 50% of habitat is accessible to fishing	50%-75% of habitat is accessible to fishing	>75% of habitat is accessible to fishing
Schooling, aggregation, or other behavior responses affecting capture	Low susceptibility to capture (specific behaviors depend on gear type)	Average susceptibility to capture (specific behaviors depend on gear type)	High susceptibility to capture (specific behaviors depend on gear type)
Morphological characteristics affecting capture	Low susceptibility to capture (specific characteristics depend on gear type)	Average susceptibility to capture (specific characteristics depend on gear type)	High susceptibility to capture (specific characteristics depend on gear type)
Bycatch or actively targeted by the fishery	No targeted fishery	Occasionally targeted, but occurs in a mix with other species in catches	Actively targeted
Natural mortality compared to dominant species in the fishery	Natural mortality higher or approximately equal to dominant species ($M \geq M$)	Natural mortality equal to dominant species ($M \approx M$)	Natural mortality less than dominant species ($M < M$)
Rarity	Sporadic occurrence in catch	Not uncommon, mostly pure catches are possible with targeting	Frequent occurrence in catch
Value or desirability	Low value (< $1.00/lb, often not retained (< 33% of the time)	Moderate value ($1.00 - $2.25), usually retained (34-66% of the time)	Very valuable or desirable (e.g., > $2.25/lb), almost always retained (>66% of the time).
Trend in catches (use only when effort is stable)	Catch trend increasing or stable (assign score of 1.5)	Catch trend increasing or stable (assign score of 1.5)	Decreasing catches

Table 8-8. Best practice mitigation measures by fisheries and gear type. Source: Marine Stewardship Council Science Series, Correspondence: Indrani Lutchman Email: ilutchman@gmail.com. A review of best practice mitigation measures to address the problem of bycatch in commercial fisheries Indrani Lutchman, Independent Fisheries Consultant based in London.

Appendix 4. Best practice mitigation measures by fisheries and gear type

Fisheries	Gear type	Bycatch	Mitigation measures	Implemented in fisheries
Tuna fisheries/small pelagics (Gilman, 2011)	Purse seines	Cetaceans	Restrict setting of FADs or other aggregating devices Prohibition of night sets Conducting backdown after the dolphins are captured Use of the 'medina dolphin safety panel'	IATTC SPREFO
		Turtles	Not setting on turtles Deploying boats to assist with the release of turtles Turtle excluder devices	
Toothfish/Deepwater species (SC-CCAMLR, 2006)	Demersal longlines	Seabirds	Night setting Under-water setting of hooks Ban on discharging of offal off the side of boats Bird scaring devices on the deck e.g. tori poles	CCAMLR
		Sharks/skates/rays	Move on rule	
Large pelagic fisheries (Gilman,2011)	Pelagic long lines	Seabirds	Night setting Under-water setting of hooks Ban on discharging of offal off the side of boats Bird scaring devices on the deck e.g. tori poles	IOTC
		Turtles	Wider hooks with large fish bait[15] Deeper setting to deploy hooks	
Shrimp fisheries (Kennedy, 2007)	Pelagic trawls	Turtles	Avoiding hotspots Not using FADs or other aggregating devices Turtle excluder devices	US (Gulf of Mexico fisheries)
Small pelagics (Hall, 2000)	Gillnets	Cetaceans	Pingers Weak lines on buoys to break away before entanglement	US

Table 8-9. Fisheries research characteristics and categories in New Zealand, identifying different procurement strategies.

Table 2. Fisheries research categories and characteristics.

Type of Research	Key Characteristics	Potential procurement strategies (to test via EOI)
Trawl surveys	• Need large investment to ensure same vessel without modifications available over decades • Need significant scientist/technician team for long periods • Few providers • Each survey is expensive; cannot repeat because time-specific; therefore, require strict quality assurance • Time series impossible to repeat • Likely not enough trawl survey work to justify full time vessel (i.e., likely need to bundle with other work; initially fisheries but also non-fisheries work) • Currently approximately 60 – 80 days per year on the *RV Tangaroa* (2 – 3 trawl surveys per year; Deepwater is looking to increase to 3 – 4); • Currently 40 – 100 days per year (average 65) on the *RV Kaharoa*	• Use of longer contracts • Bundle contracts based on type of vessel e.g., deepwater and inshore • Costs of transitioning to vessel other than *RV Tangaroa* must be factored in • Develop a preferred provider to ensure consistency in sampling techniques
Acoustic surveys	• Need access to suitable vessels but no requirement for continuity of vessel • Can use dedicated RV or commercial vessel, although latter may need some modifications if towed body used • Need significant scientist/technician team for long periods • Relatively few providers • Each survey is expensive, cannot repeat because time-specific; therefore, require strict quality assurance • Only suitable for relatively few species (single species; spawning or feeding aggregations; target strength known) • Regular acoustic surveys conducted each year; currently 30 days on *RV Tangaroa* per year, plus additional days on industry vessels.	• Contracts likely more than one year but does not need to be as long as for trawl. • Bundle contracts by fishery grouping e.g. deepwater • May need to consider including acoustic and trawl surveys in deepwater contract bundle if required to make economic package • Encourage industry to tender • Develop a preferred provider to ensure consistency in sampling techniques
Video surveys	• Similar to acoustic surveys • *Ad-hoc* video survey programme, not necessarily conducted yearly	• Contracts likely more than one year but does not need to be as long as for trawl.
Tagging	• Note: there are different types of tagging (e.g., for growth, migration, stock assessment studies; and for HMS and rock lobster). • Technical skills and experience required • Location specific • Each survey is expensive; therefore, require strict quality assurance • Ad-hoc tagging programme, not necessarily conducted yearly • Have used industry vessels and observers in past to reduce cost	• Project-by-project contracting? • Or consider multi-year contracts
Fishery characterisations	• Technical skills and experience required • Some location non-specific (desktop studies) but local knowledge also required • Relatively low cost and relatively easily repeatable	• Nature of work and low capital cost mean this type of work could be bundled in different ways to encourage different types of providers
Shed sampling	• Technical skills and experience required • Location specific – many locations • Medium cost; cannot repeat because time-specific.	• Contracts likely more than one year but does not need to be as long as for trawl. • Bundle into one contract, or • Bundle by region to reduce operating costs
Fisheries modelling (stock assessment/CPUE analysis/yield per recruit	• Requires high level expertise/experience; shortage of appropriate skills • Market comprises large providers and boutique companies and individuals • Each piece of work is repeatable at moderate cost • Location partly non-specific; data transferable by email & web but local knowledge is essential • Essential to maintain and enhance capacity within New Zealand.	• Use of longer contracts. • Consider using a range of bundle types (fisheries and duration) to encourage maintenance and expansion of existing market • Test willingness of smaller providers to collaborate on large contracts • Need to recognise New Zealand and world-wide shortage of skills in this area
Laboratory analysis: aging (otoliths & vertebrae); chemical and isotope analysis	• Requires high level expertise/experience • Requires moderate investment in specialist equipment and training; some overlap with non-fisheries research • Each piece of work is repeatable at moderate cost • Location non-specific; samples transferable by courier	• Use of longer contracts • Consider contracting in at least two bundles to help ensure maintenance of NZ capacity • Careful quality control required; more difficult to do with offshore providers.
Protected species and habitats; adverse effects	• Data collection similar to local population surveys although higher cost due to remote locations • Protected species modelling similar to fisheries modelling in terms of the levels of expertise required.	• Duration to depend on nature of work • Bundled by species or species assemblages e.g., Seabirds
Ecosystem research and trophic linkages	• Survey work varies from small-scale to large, vessel-based surveys • Ecosystem modelling similar to fisheries modelling	• Yearly contracting • Individual projects let • Work with FRST
Recreational catch and value surveys	• Requires high level expertise/experience planning and analysis • High level of technical skills required • Either location specific (e.g., boat ramps) or location non-specific (e.g., phone and web surveys). • Each survey is expensive; therefore, require strict quality assurance	• Project-by-project contracting – note some projects are multi-year • Possibly develop a preferred provider to ensure consistency in sampling techniques
Local population surveys (e.g., eels; cockles)	• Technical skills and experience required • Location specific • Relatively low cost; cannot repeat because time-specific	• Yearly contracting • Bundle by region or by fishery • Encourage alternative providers (e.g. universities, iwi) to tender.

Table 8-10. Assessment of progress of RFMOs to which the USA is a member towards EBFM after NOAA (2014).

TABLE 6. EBFM IN REGIONAL FISHERY MANAGEMENT ORGANIZATIONS TO WHICH THE UNITED STATES IS MEMBER

	IATTC	WCPFC	IPHC	PSC	CCBSP	ICCAT	NAFO	NASCO	WECAFC	CCAMLR	IOTC
Does the RFMO have ecosystem science on its research agenda?	YES	NO	NO	YES	NO	YES	YES	YES	YES	YES	YES
Does the RFMO have an ecosystem advisory committee?	YES	NO	NO	NO	NO	YES	YES	YES	NO	YES	YES
Does the RFMO make decisions using ecosystem information?	NO	NO	YES	YES	NO	NO	YES	YES	YES	YES	NO
Does the RFMO articulate an ecosystem goal in management?	YES	NO	NO	NO	YES	YES	YES	YES	YES	YES	NO
Does the RFMO have a fishery management plan that is ecosystem-based?	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	NO
Does the RFMO use ecosystem science in any other way in management?	YES	YES	NO	YES	NO	YES	YES	YES	YES	YES	YES

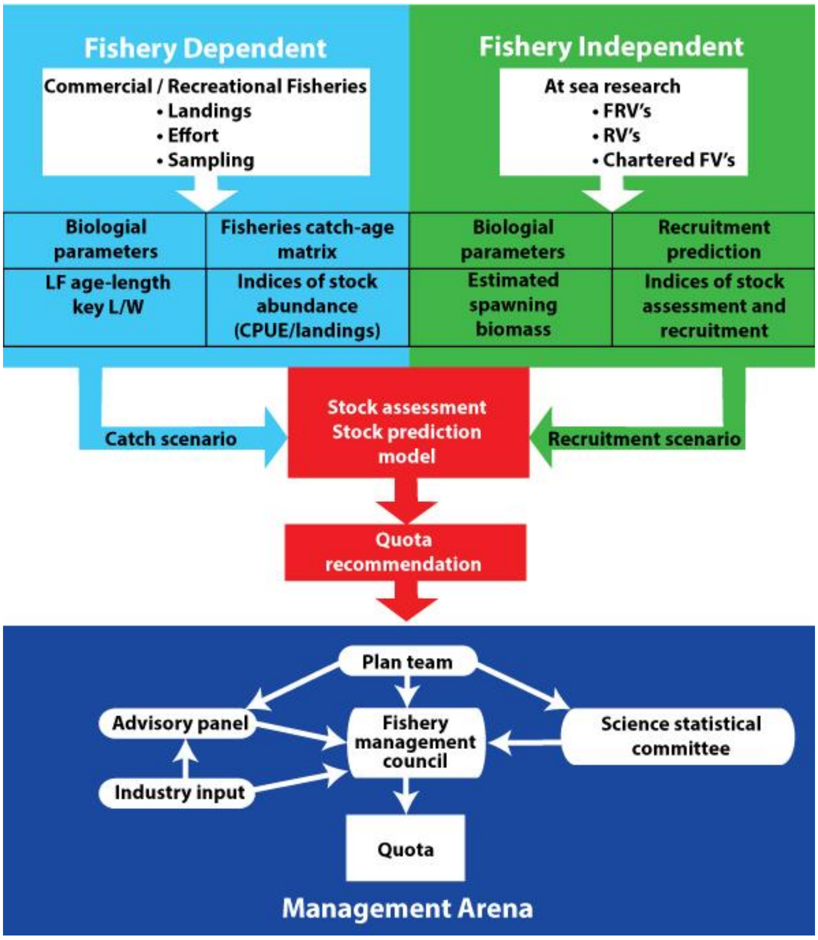

Figure 8-1. A schematic of the data collection procedure for fisheries dependent and fisheries independent data sources, followed by stock assessments and management advice formulation, and then the actual management approach - based on the situation in the USA.

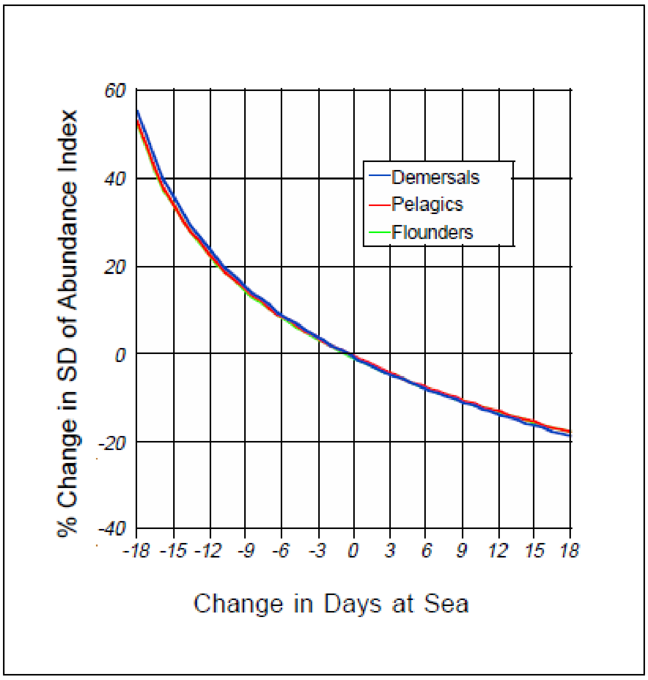

Figure 7. Change in precision of autumn bottom trawl surveys for Northeast pelagic and demersal fish and flounders with change in survey length from the standard 48-day duration (lines are almost identical and thus overlay one another).

Figure 8-2. An extract from NOAA (1998) illustrating the decision making processes underlying decisions to commission 4 new FRVs for fisheries independent surveys in the USA, run by NOAA. The graph shows the trade-off bettwen days ar sea and the change in the standard error in the abundance index generated from research surveys.

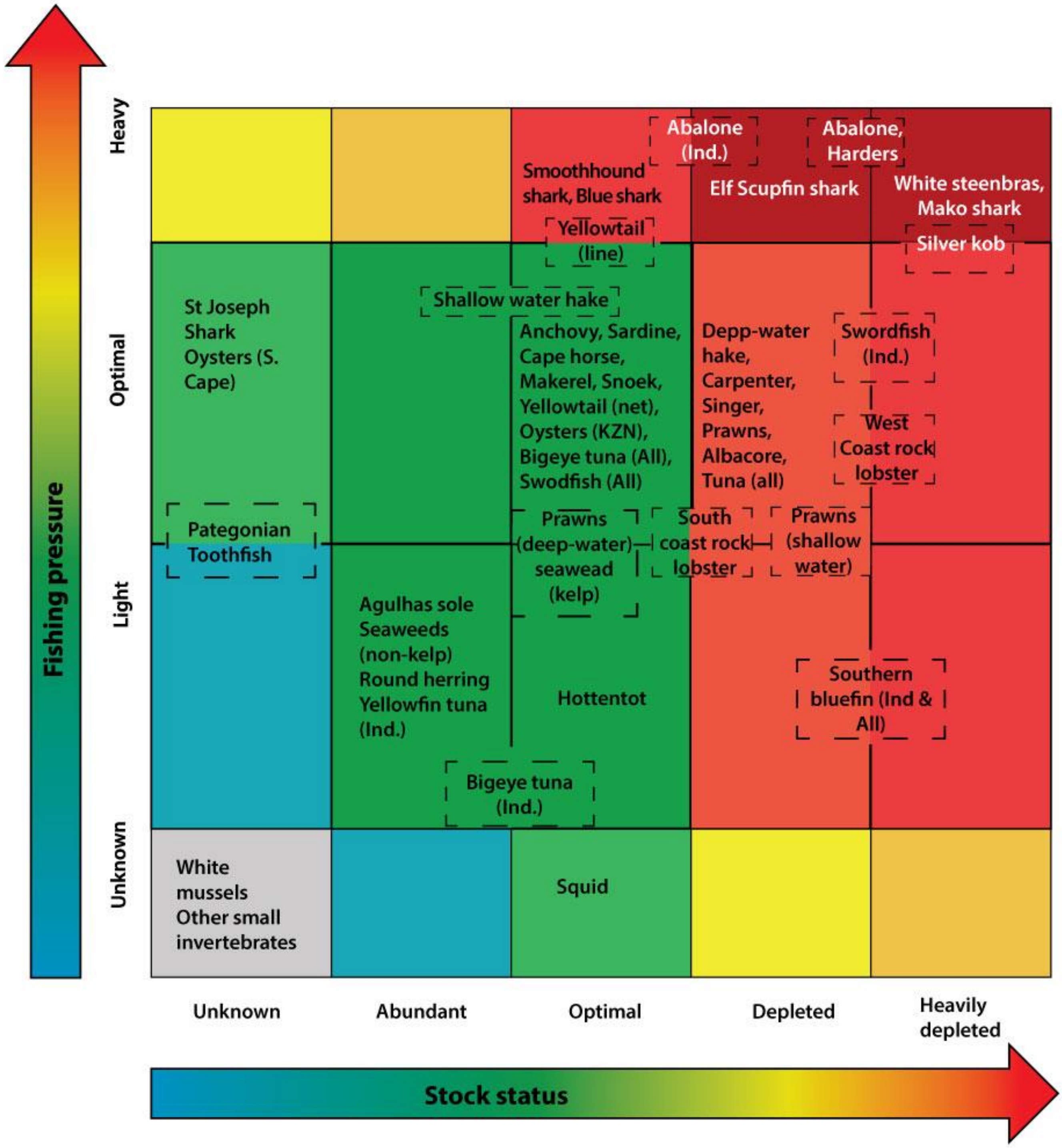

Figure 8-3. DAFF (2014) summary of stock status.