FINAL

An Impact Assessment of FRDC Investment in Project: 2013-053: Summer spawning patterns and preliminary Daily Egg Production Method survey of Jack Mackerel and Sardine

Agtrans Research

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An Impact Assessment of FRDC Investment in Project: 2013-053: Summer spawning patterns and preliminary Daily Egg Production Method survey of Jack Mackerel and Sardine
Project 2016-134

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

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Tim Ward, Science Leader (Marine Ecosystems) and Principal Scientist (Pelagic Fishes), South Australian Research and Development Institute

Abbreviations

ABS	Australian Bureau of Statistics
AFMA	Australian Fisheries Management Authority
CRRDC	Council of Rural Research and Development Corporations
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAWR	Department of Agriculture and Water Resources
DEE	Department of Environment and Energy
DEPM	Daily Egg Production Method
FRDC	Fisheries Research and Development Corporation
HSP	Harvest Strategy Policy
NSW	New South Wales
TAC	Total Allowable Catch
RD&E	Research, Development and Extension
SARDI	South Australian Research and Development Institute
SEMAC	South East Management Advisory Committee
SPF	Small Pelagic Fishery
UTAS	University of Tasmania

Executive Summary

What the report is about

This report presents the results of an impact assessment of a Fisheries Research and Development Corporation (FRDC) investment in the *Summer spawning patterns and preliminary Daily Egg Production Method survey of Jack Mackerel and Sardine off the East Coast*. The project was funded by FRDC over the period December 2013 to September 2015.

Methodology

The investment was analysed qualitatively within a logical framework that included activities and outputs, outcomes and impacts. Impacts were categorised into a triple bottom line framework. Principal impacts identified were then valued. Benefits were estimated for a range of time frames up to 30 years from the year of last investment. Past and future cash flows were expressed in 2016/17 dollar terms and were discounted to the year 2016/17 using a discount rate of 5% to estimate the investment criteria.

Results/key findings

The major impact identified was of a financial nature. However, some social impacts were also identified but not valued. This included the enhanced social licence to operate in the Small Pelagic Fishery, due to the scientific robust biomass estimates resulting from the project. It is expected that the licence holders for Jack Mackerel in the Small Pelagic Fishery will be the primary beneficiary of the investment.

Investment Criteria

Total funding from all sources for the project was $0.68 million (present value terms). The value of benefits was estimated at $1.45 million (present value terms). This gave an estimated net present value of $0.78 million, and a benefit-cost ratio of 2.2 to 1.

Conclusions

The investment in this project has likely resulted in increased profits for licence holders of Jack Mackerel in the Small Pelagic Fishery due to the increase in Total Allowable Catch. There is also an increased confidence in the fisheries management of the Small Pelagic Fishery, as there is increased information that Total Allowable Catch is scientifically robust and will maintain the ecological integrity of the fishery. The increased social licence also is another main benefit, due to the scientific robustness of the biomass estimates.

Keywords

Jack Mackerel, Trachurus declivis, Australian Sardine, Sardinops sagax, Daily Egg Production Method, Spawning Biomass, Small Pelagic Fishery, eastern Australia, Tasmania, Bass

Introduction

The Fisheries Research and Development Corporation (FRDC) required a series of impact assessments to be carried out annually on a number of investments in the FRDC research, development and extension (RD&E) portfolio. The assessments were required to meet the following FRDC evaluation reporting requirements:

- Reporting against the FRDC 2015-2020 RD&E Plan and the Evaluation Framework associated with FRDC's Statutory Funding Agreement with the Commonwealth Government.
- Annual Reporting to FRDC stakeholders.
- Reporting to the Council of Rural Research and Development Corporations (CRRDC).

The first series of impact assessments included 20 randomly selected FRDC investments worth a total of approximately $6.31 million (nominal FRDC investment). The investments were selected from an overall population of 136 FRDC investments worth an estimated $24.98 million (nominal FRDC investment) where a final deliverable had been submitted in the 2015/16 financial year.

The 20 investments were selected through a stratified, random sampling process such that investments chosen spanned all five FRDC Programs (Environment, Industry, Communities, People and Adoption), represented approximately 25% of the total FRDC RD&E investment in the overall population (in nominal terms) and included a selection of small, medium and large FRDC investments.

Project 2013-053: *Summer spawning patterns and preliminary Daily Egg Production Method survey of Jack Mackerel and Sardine off the East Coast* was selected as one of the 20 investments and was analysed in this report.

General Method

The impact assessment followed general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including Research and Development Corporations, Cooperative Research Centres, State Departments of Agriculture, and some Universities. This impact assessment uses Cost-Benefit Analysis as its principal tool. The approach included both qualitative and quantitative descriptions that are in accord with the impact assessment guidelines of the CRRDC (CRRDC, 2014).

The evaluation process involved identifying and briefly describing project objectives, activities and outputs, outcomes, and impacts. The principal economic, environmental and social impacts were then summarised in a triple bottom line framework.

Some, but not all, of the impacts identified were then valued in monetary terms. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, a high degree of uncertainty surrounding the potential impact, or the likely low relative significance of the impact compared to those that were valued. The impacts valued are therefore deemed to represent the principal benefits delivered by the project. However, as not all impacts were valued, the investment criteria reported potentially represent an underestimate of the performance of the investment.

Background and Rationale

Background

The Small Pelagic Fishery (SPF) is a Commonwealth fishery that covers almost the entire southern waters of the Australian continent, from the Queensland-New South Wales (NSW) border to the north of Perth, Western Australia, while the eastern SPF covers the waters from the middle of the Bass Straight to the Queensland-NSW border. The fishery is for the capture of Australian Sardine, Blue Mackerel, Jack Mackerel, and Red Bait fish.

It is recognised that the Daily Egg Production Method (DEPM) is the most accurate stock estimate for pelagic fish. This is recognised in the methods Tier 1 status for estimating Total Allowable Catch (TAC) in the Harvest Strategy Policy (HSP). Currently, the use of mid-water pair trawling is allowed in the SPF as well as mid-water trawl and purse seine fishing (AFMA, 2017a).

Rationale

It is recognised that Australian fisheries are the best managed in the world and that up to date stock assessments are needed to keep this status. The project was funded because the Resource Assessment Group for the SPF identified that scientific biological stock assessments in the SPF were needed to determine an appropriate TAC. This project was funded to gain a greater understanding of the biological stock levels and to aid community concerns over the sustainable level of catch in the SPF.

There had been no DEPM project specifically for Jack Mackerel or Australian Sardine in the SPF. There was a 2002 DEPM estimation for Jack Mackerel by (Neira, 2011) but the project used plankton samples that were incidentally caught. Information on the spawning patterns of the Jack Mackerel and Australian Sardine was identified as being required to underpin the assessment of the status of the species. The DEPM survey focused on the eastern SPF as without this DEPM survey, the TAC of Jack Mackerel in the eastern SPF would have dropped in line with fishery regulations.

There was also a need to prove that TAC decisions in the SPF are based on the best scientific estimates, to ensure trust in the management of the fishery and the associated maintenance of the social licence of the fishing activity.

Project Details

Summary

Project Code: 2013-053
Title: *Summer spawning patterns and preliminary Daily Egg Production Method survey of Jack Mackerel and Sardine off the East Coast*
Research Organisation: South Australian Research and Development Institute (SARDI)
Principal Investigator: Tim Ward
Period of Funding: December 2013 to September 2015

Objectives

The project had three objectives:

1. To establish methods of estimating adult reproductive parameters of Jack Mackerel and Australian Sardine off the east coast
2. To determine distribution and abundance of eggs and larvae of Jack Mackerel and Australian Sardine off the east coast during summer
3. To produce preliminary estimates of the spawning biomass of Jack Mackerel and Australian Sardine off the east coast during summer

Logical Framework

Table 1 provides a brief description of the project in a logical framework.

Table 1: Logical Framework for Project 2013-053

Activities and Outputs	• This project was the first large spawning estimation that specifically targets Jack Mackerel and the Australian Sardine off the East Coast of the SPF in the summer period. The sardine estimation targeted spawning in the Northern Tasmanian region. • Surveys were conducted in 2014 when samples of plankton (fish eggs) were collected from 117 of the 292 stations from South East Cape, Tasmania to Port Stephens, NSW for both Jack Mackerel, and Australian Sardine. • Adult Jack Mackerel samples were taken from fish trawls across 20 locations from St Helens, Tasmania to Eden, NSW. Samples were collected during the day to get a representative population of spawning and non-spawning stock. • As adult samples were not taken for the Australian Sardine, the project used estimates of adult sardine numbers from a previous study on adult sardine reproductive parameters in South Australia. • The project team estimated batch fecundity from ovaries and spawning fraction of mature Jack Mackerel females caught. The sex ratio, and male and female weight of Jack Mackerel caught were also measured. Estimates from a previous study were used for Australian Sardine. This was so an approximate biomass for east coast Australian Sardine could be estimated. • DEPM analysis was then used to estimate the biomass of the existing Jack Mackerel and Australian Sardine populations. • The DEPM was based on total spawning area, mean egg production, mean female weight, the proportion of spawning females, the ratio of males to females, and batch fecundity.

	• Egg identification was carried out to estimate summer egg production using laboratory analysis to determine the spawning biomass of both Jack Mackerel and Australian Sardines. • The DEPM parameters for the Jack Mackerel provided robust estimates for most parameters, except batch fecundity due to a small sample size. However, estimates for batch fecundity found were in the range of other similar species to the Jack Mackerel. • The spawning areas of the Jack Mackerel and Australian Sardine were estimated to be 37% of the sampled area of each species. • The DEPM estimated the spawning biomass of Jack Mackerel to be 157,805 tonnes (t), with a 95% Confidence Interval of 59,570 t – 358,731 t. This was considered a reasonable range based on existing literature, suggesting the project results were robust. • Results showed that sardines spawned in January and that the biomass of the sardine population is approximately 10,962 t during summer. The main spawning area for the Australian Sardine was around southern Victoria and northern Tasmania. This biomass estimate was noted as an underestimation and not an accurate result as no adult sardines were sampled during the project.
Outcomes	• The DEPM analysis for Jack Mackerel enabled Tier 1 estimates of biomass for to be made for the eastern SPF. The survey enabled regulations to increase the TAC for Jack Mackerel based on scientific evidence that it is sustainable to do so. • Based on the project findings, the total biomass estimate for Jack Mackerel in the eastern SPF was afforded Tier 1 status. As a result, the TAC for Jack Mackerel was increased from 10,230t to 18,670t in 2015/16 in the eastern SPF. The TAC was then increased further to 18,880 in 2017/18 due to lower state fishery catches of Jack Mackerel. • Due to the TAC increase, it is now potentially economically viable to use pair trawling to capture the total TAC of Jack Mackerel. • Due to survey limitations, the biomass estimated could not be used for input into the TAC for Australian Sardine. However, the data from the study contributed to another stock assessment of the Australian Sardine, with information from the project being used in FRDC Project 2014/033. • The project results were used in FRDC's 2016 Fish Status Report for Jack Mackerel and Australian Sardine. The report estimates the sustainability of the fish stocks through an understanding of the biomass of the fish. • Environmental and recreational fishing members in the Australian Fishing Management Authority’s (AFMA) South East Management Advisory Committee (SEMAC) agreed on Jack Mackerel TAC in eastern SPF in line with other groups on the SEMAC. • There was an increase in confidence of fisheries management of the SPF by stakeholders. As the results of the project are scientifically robust, the associated biomass decisions of the SPF are trusted.
Impacts	• Potential increased profit for fishers of Jack Mackerel in the eastern SPF due to an increased TAC. • Maintenance of social licence for fisheries managers and licence holders to operate in the SPF through the knowledge that Jack Mackerel fish stocks are sustainable with TAC limits set based on scientifically robust estimation methods. • Increased knowledge and research capacity associated with the SPF.

Project Investment

Nominal Investment

Table 2 shows the annual investment for the project funded by FRDC. FRDC Projects 2013-053.2 and 2013-053.3 costs have been included in the nominal investment as their funding is directly related to the project. The funds from these sub-projects were used to hire the boats for the DEPM surveys.

There were other contributors to the investment including the Commonwealth Department of Agriculture and Water Resources (DAWR), SARDI, and the University of Tasmania (UTAS): Institute for Marine and Antarctic Studies.

The contributions of the other funders are totalled in Table 2 and listed in Table 3.

Table 2: Annual Investment in the Project 2013-053 (nominal $)

Year ended 30 June	FRDC ($)	OTHER ($)	TOTAL ($)
2014	270,858	25,000	295,858
2015	100,000	125,000	225,000
2016	22,000	0	22,000
Totals	392,858	150,000	542,858

Table 3: Annual Investment by Individual other Contributors in the Project 2013-053 (nominal $)

Year ended 30 June	DAWR ($)	SARDI ($)	UTAS ($)	TOTAL ($)
2014	0	15,000	10,000	25,000
2015	100,000	15,000	10,000	125,000
Totals	100,000	30,000	20,000	150,000

Program Management Costs

For the FRDC investment, the cost of managing the FRDC funding was added to the FRDC contribution for the project via a management cost multiplier (1.115). This multiplier was estimated based on the share of ‘employee benefits' and ‘supplier' expenses' in total FRDC expenditure reported in the FRDC Cash Flow Statement (FRDC, 2016). This multiplier then was applied to the nominal investment by FRDC shown in Table 2.

Real Investment and Extension Costs

For the purposes of the investment analysis, the investment costs of all parties were expressed in 2016/17 dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2016). No additional costs of extension were included.

Impacts

Table 4 provides a summary of the principal types of impacts summarised from those listed in Table 1 and categorised into economic, environmental and social impacts.

Table 4: Triple Bottom Line Categories of Principal Impacts from the DEPM estimates of Jack Mackerel in the SPF

Economic	• Potential increased profit for SPF fishers of Jack Mackerel
Environmental	• Nil, but the existing ecological integrity of the fishery was maintained in the revised TAC
Social	• Increased knowledge and research capacity • Enhanced social licence for fishery managers and fishers in the SPF

Public versus Private Impacts

As the major impacts are private in nature, the majority of the impacts will be captured by the licence holders of Jack Mackerel in the SPF. There are also positive public impacts with increased capacity of research and increased trust by the public in fisheries management to make science-based decisions.

Distribution of Private Impacts

The private impacts will initially be received by the Jack Mackerel fishers, but these will eventually be shared by others in the supply chain. Any impact from the enhanced social licence also will be captured by licence holders in the SPF.

Impacts on other Australian industries

There are unlikely to be impacts on other Australian industries.

Impacts Overseas

There are unlikely to be any impacts overseas.

Match with National Priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 4. The project findings and related impacts will contribute primarily to Rural RD&E Priorities 1, 3, and 4 and to Science and Research Priority 2.

Table 5: Australian Government Research Priorities

Australian Government	
Rural RD&E Priorities (est. 2015)	**Science and Research Priorities (est. 2015)**
1. Advanced technology 2. Biosecurity 3. Soil, water and managing natural resources 4. Adoption of R&D	1. Food 2. Soil and Water 3. Transport 4. Cybersecurity 5. Energy and Resources 6. Manufacturing 7. Environmental Change 8. Health

Sources: (DAWR, 2015) and (OCS, 2015)

Valuation of Impacts

Impacts Valued

The analysis was undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions, particularly when a high degree of uncertainty was involved. Sensitivity analyses were undertaken for those variables where there were the greatest uncertainties and for those that were identified as key drivers of the investment criteria.

One key impact of the project was valued. This was the increased profits from the increase in TAC for Jack Mackerel in the eastern SPF.

Impacts Not Valued

Not all impacts identified in Table 3 could be valued in the assessment. The social impacts identified but not valued included:

- Increased knowledge and research capacity
- Increased social licence to manage and use the SPF

These social impacts could not be valued due to a lack of baseline data and resources, and uncertainties around future impacts.

Valuation of Impact: Increased Profits to Fishers of Jack Mackerel

The TAC and Expected Catches with and without the Project

Without the project, it is assumed that there would have been no new DEPM calculation for Jack Mackerel. As there would have been no DEPM, a Tier 1 for the fishery would not have been possible, so a Tier 2 and Tier 3 TAC would have been based on an estimated biomass of approximately 140,000 t (based on Neira, 2011).

It is assumed that the Tier 2 TAC without the project would have been 8,400 t in 2015/16 (6% of biomass) followed by a decrease to a Tier 3 TAC of 4,200 t (3% of biomass) as per the HSP for the SPF in 2016/2017.

The probability of all the Tier 2 and Tier 3 TAC tonnages being caught by fishers is assumed to be 20% and 40% respectively. The estimated catches if all the TAC allocation is not caught are 5,325 t for Tier 2 and 107 t for Tier 3. These figures are based on recent averages of previous catches of Jack Mackerel in the SPF.

A summary of these assumptions is provided in Table 6.

Table 6: Expected Catch without Project 2013-053

Year	TAC tonnes (Tier)	Probability of full TAC being caught (a)	Catch if full TAC not caught (tonnes) (b)	Probability of full TAC not being caught	Expected catch (tonnes)
2015/16	8,400 (2)	20%	5,325[1]	80%	20% x 8,400 + 80% x 5,325 = 5,940
2016/17	4,200 (3)	40%	107[2]	60%	40% x 4,200 + 60% x 107 = 1,744
…					
2044/45	4,200 (3)	40%	107	60%	1,744

(a) Assumption by Agtrans Research
(b) Based on historical catch (AFMA 2016 and 2017b) (DEE, 2014)

[1] Based on the average of previous two years of catch, where Tier 1 TAC was used (AFMA, 2016), (AFMA, 2017b).
[2] Based on average catch of Jack Mackerel in SPF between 2008/09 – 2011/12 (DEE, 2014).

As a result of the project, a Tier 1 biological stock estimate for the Jack Mackerel in the eastern SPF was used by AFMA in setting the TAC in 2015/16. This increased the TAC of Jack Mackerel from 10,230 t to 18,670 t in 2015/16. For the 2016/17 and 2017/18 seasons, the new Tier 1 TAC is 18,880 t[3] (AFMA, 2017d). The Tier 1 status from Project 2013-053 is valid for 5 years, when another Tier 1 assessment must be undertaken if Tier 1 status is to be maintained (AFMA, 2017a). For the 2015/16 and 2016/17 seasons, a Tier 1 TAC was allowed in the SPF for Jack Mackerel, with catches of 6,585 t (AFMA, 2016) and 4,065 t (AFMA, 2017b) respectively.

As stated earlier, the Tier 1 status of the DEPM survey will last for 5 years, before moving to a Tier 2 status for another 10 years. According to HSP rules, the TAC will be 6% of estimated biomass at Tier 2 Status, and 3% at Tier 3 status. It is possible that because of the project, extra scientific evidence can be used to increase the TAC above 6% and 3% of biomass in line with the HSP rules (AFMA, 2017a, p. 10). The current valuation assumes a TAC of 6% and 3% of biomass as conservative estimates, as it is uncertain what future evidence may be assembled.

As historical catch rates have been lower than the original and new TAC (AFMA, 2017c), a probability factor is applied to the proportion of the total TAC caught. From the latest AFMA catch records, only 20% of the TAC for 2016/17 was caught. For the future probability of catching the full TAC allocation, a 10% probability has been assigned for Tier 1, as the higher TAC should increase the incentives for catching the full quota. For Tier 2 and Tier 3 estimates, a probability of 20% and 40% has been assigned respectively.

For Tier 1 and 2 estimates, the alternative catch for Jack Mackerel if the TAC is not caught is the average catch of Jack Mackerel of the last two fishing seasons where Tier 1 estimates have been in effect. For Tier 3 estimates, a catch of 107 t (DEE, 2014) is assumed, based on an approximate average of Jack Mackerel catch from 2008/09 to 2010/11 when TAC was previously at a Tier 3 level. This impact assessment does not consider possible future Tier 1 assessments. While these future assessments are probable, they lie well into the future. Therefore, future biomass decisions for Jack Mackerel are impossible to accurately predict.

A summary of these assumptions is provided in Table 7.

Table 7: Expected Catch with Project 2013-053

Year	**TAC tonnes (Tier)**	**Probability of full TAC being caught (tonnes) (a)**	**Catch if full TAC not caught (tonnes) (b)**	**Probability of full TAC not being caught**	**Expected catch (tonnes) (c)**
2015/16	18,660 (1)	0%	6,585	100%	6,585
2016/17	18,880 (1)	0%	4,065	100%	4,065
2017/18	18,880 (1)	10%	5,325	90%	6,681
2018/19	18,880 (1)	10%	5,235	90%	6,681
2019/20	18,880 (1)	10%	5,325	90%	6,681
2020/21	9468 (2)	20%	5.325	80%	6,154
…					
2029/30	9468 (2)	20%	5,325	80%	6,154
2030/31	4,734 (3)	40%	107	60%	1,958
..					
2044/45	4,734 (3)	40%	107	60%	1,958

(a) Assumption by Agtrans Research
(b) Based on historical catch (AFMA 2016 and 2017b) (DEE, 2014)
(c) Based on weighted probabilities as shown in Table 6

[3] The change from 18,660 t to 18,880 t is due to a change in state jurisdictions catch of Jack Mackerel. For simplicity, future assumptions for Tier 1 TAC, 18,880 t are used.

Valuation of Additional Catch

The value of Jack Mackerel is not available, due to being a small value fishery and with the commercial value of the SPF Jack Mackerel not available for commercial reasons. For this impact assessment, the gross value of Australian Sardines is used as a proxy, as both are small pelagic fish fished in the SPF. Assumptions addressing the valuation of the additional catch are provided in Table 8.

Summary of Assumptions

A summary of assumptions is provided below in Table 8.

Table 8: Summary of Assumptions

Variable	Assumption	Source
Estimated biomass from DEPM without project	140,000 tonnes	Neira, 2011
New estimated biomass of Jack Mackerel from DEPM	157,805 tonnes	Ward, et al., 2015
TACs and Expected Catch without the project	See Table 6	Agtrans Research based on AFMA, 2017a
TACs and Expected Catch with the project	See Table 7	Agtrans Research based on AFMA, 2017a
Gross value of Jack Mackerel	$617 tonne	ABARES, 2016
Profit as percentage of gross value	5%	Agtrans Research
Profit from Gross value	$30.85 tonne	5% * $617
Tier 1 percentage of biomass	12%	AFMA, 2017a
Tier 2 percentage of biomass	6%	AFMA, 2017a
Tier 3 percentage of biomass	3%	AFMA, 2017a

Results

All benefits after 2016/17 were expressed in 2016/17 dollar terms. All costs and benefits were discounted to 2016/17 using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the Modified Internal Rate of Return. The base analysis used the best available estimates for each variable, notwithstanding a level of uncertainty for many of the estimates. All analyses ran for the length of the project investment period plus 30 years from the last year of investment in Project 2013-053 (2015/16).

Investment Criteria

Tables 9 and 10 show the investment criteria estimated for different periods of benefits for the total investment and the FRDC investment.

Table 9: Investment Criteria for Total Investment in Project 2013-053

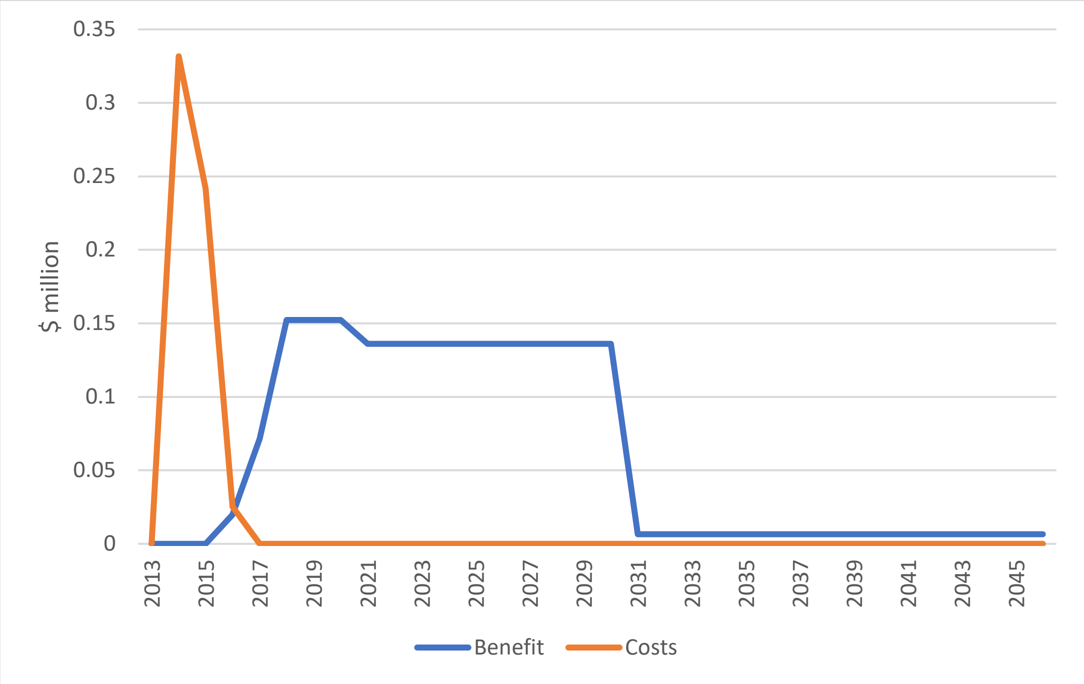
Investment Criteria	**Years after Last Year of Investment**						
	0	5	10	15	20	25	30
Present Value of Benefits ($)	0.02	0.62	1.10	1.42	1.43	1.44	1.45
Present Value of Costs ($)	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Net Present Value ($)	-0.66	-0.06	0.43	0.74	0.76	0.77	0.78
Benefit-Cost Ratio	0.03	0.91	1.63	2.10	2.12	2.13	2.15
Internal Rate of Return (%)	neg.	2.97	13.34	15.74	15.80	15.82	15.83
Modified Internal Rate of Return (%)	neg.	2.61	11.01	10.83	9.32	8.44	7.86

Table 10: Investment Criteria for FRDC Investment in Project 2013-053

Investment Criteria	**Years after Last Year of Investment**						
	0	5	10	15	20	25	30
Present Value of Benefits ($)	0.02	0.46	0.82	1.06	1.07	1.07	1.08
Present Value of Costs ($)	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Net Present Value ($)	-0.49	-0.05	0.31	0.55	0.56	0.57	0.57
Benefit-Cost Ratio	0.03	0.91	1.62	2.08	2.10	2.12	2.13
Internal Rate of Return (%)	neg.	2.89	13.07	15.46	15.51	15.54	15.55
Modified Internal Rate of Return (%)	neg.	2.46	10.94	10.78	9.29	8.42	7.84

The annual undiscounted benefit and cost cash flows for the total investment for the duration of Project 2013-053 plus 30 years from the last year of investment are shown in Figure 1.

Figure 1: Annual Cash Flow of Undiscounted Total Benefits and Total Costs



Sensitivity Analyses

Several sensitivity analyses were conducted. A sensitivity analysis was carried out on the discount rate (Table 11). The analysis was performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values. Benefits from year 2030/31 to 2045/46 are relatively small and do not show in Figure 1.

Table 11: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($)	2.01	1.45	1.12
Present value of costs ($)	0.60	0.68	0.76
Net present value ($)	1.42	0.78	0.35
Benefit-cost ratio	3.37	2.15	1.46

A sensitivity analysis was undertaken on the assumption of the probability of full utilisation of the TAC being caught and the level of catch if TAC was not reached. The counterfactual remained static during the sensitivity analysis.

Table 12: Sensitivity to Probability of TAC being Fully Utilised for Tier 1 and 2
(Total investment, 30 years)

Investment Criteria	Sensitivity to Probability of Full Utilisation of TAC		
	Tier 1, Tier 2: 0%	Tier 1: 10% Tier 2: 20% (base)	Tier 1: 20% Tier 2: 40%
Present value of benefits ($)	1.17	1.45	2.14
Present value of costs ($)	0.68	0.68	0.68
Net present value ($)	0.49	0.78	1.46
Benefit-cost ratio	1.73	2.15	3.15

A sensitivity analysis was undertaken on the level of catch assumed given the TAC was not fully utilised (Table 13).

Table 13: Sensitivity to Catch Levels if TAC not Utilised for Tier 1 and 2
(Total investment, 30 years)

Investment Criteria	**Sensitivity to Catch Levels if TAC not Utilised**		
	2,663 t (50% of base)	**5,325 t (base)**	**6,390 t (120% of base)**
Present value of benefits ($)	0.81	1.45	1.71
Present value of costs ($)	0.68	0.68	0.68
Net present value ($)	0.14	0.78	1.03
Benefit-cost ratio	1.20	2.15	2.52

Confidence Ratings and other Findings

The results produced are highly dependent on the assumptions made, some of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 14). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 14: Confidence in Analysis of Project

Coverage of Benefits	**Confidence in Assumptions**
Medium	Medium - Low

Only one impact was valued from the three identified. The coverage of benefits was assessed as medium, as the benefits not valued were relatively minor compared to the increased TAC. The stock assessment also contributed to the ecological integrity, that was not explicitly valued. The confidence in assumptions was also assessed as medium-low. Despite a lack of evidence that the increased TAC will be utilised, due to commercial considerations of fishers in the SPF and how future regulations may change due to unpredictable spawning and environmental factors, the confidence of assumptions assessed as medium. This is because conservative assumptions have been used in the analysis and probability factors have been applied to account for some of the uncertain outcomes.

Conclusions

The investment in this project has likely resulted in increased profits for licence holders of Jack Mackerel in the SPF due to the increase in TAC. There is also an increased confidence in the fisheries management of the SPF, as there is increased information that TAC is scientifically robust and will maintain the ecological integrity of the fishery. The increased social licence also is another main benefit, due to the scientific robustness of the biomass estimates.

Funding for project 2013-053 in 2015/16 totalled $0.68 million (present value terms) and produced estimated total expected benefits of $1.45 million (present value terms). This gave a net present value of $0.78 million, an estimated benefit-cost ratio of 2.2 to 1, an internal rate of return of 15.8% and a modified internal rate of return of 7.9%.

Several social impacts were identified but not valued. This was mainly due to the difficulty in valuing the increased social licence as a result of the project.

Glossary of Economic Terms

Cost-benefit analysis:	A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.
Benefit-cost ratio:	The ratio of the present value of investment benefits to the present value of investment costs.
Discounting:	The process of relating the costs and benefits of an investment to a base year using a stated discount rate.
Internal rate of return:	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Investment criteria:	Measures of the economic worth of an investment such as Net Present Value, Benefit-Cost Ratio, and Internal Rate of Return.
Modified internal rate of return:	The internal rate of return of an investment that is modified so that the cash inflows from an investment are re-invested at the rate of the cost of capital (the re-investment rate).
Net present value:	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.
Present value of benefits:	The discounted value of benefits.
Present value of costs:	The discounted value of investment costs.

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