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An Impact Assessment of FRDC Investment in 2011-042: TSGA IPA: clarifying the relationship between salmon farm nutrient loads and changes in macroalgal community structure/distribution (Existing Student Support)

Agtrans Research

August 2018

FRDC Project No **2016-134**

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Project 2016-134

2018

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Acknowledgments

Agtrans Research and Consulting would like to thank Patrick Hone (Executive Director) and Nicole Stubing (Project Manager) of the Fisheries Research and Development Corporation for facilitating contact with relevant project personnel and for their guidance and feedback throughout the Impact Assessment process.

Catriona Macleod – Associate Professor, University of Tasmania

Abbreviations

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
BCR	Benefit-Cost Ratio
CRRDC	Council of Rural Research and Development Corporations
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EMS	Environmental Modelling Suite
FRDC	Fisheries Research and Development Corporation
GVP	Gross Value Product
IMAS	Institute of Marine and Antarctic Studies
IMTA	Integrated Multi-Trophic Aquaculture
MIRR	Modified Internal Rate of Return
N	Nitrogen
OCS	Office of the Chief Scientist
PVB	Present Value of Benefits
RD&E	Research, Development and Extension

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 *clarifying the relationship between salmon farm nutrient loads and changes in macroalgal community structure/distribution (Existing Student Support).* The project was funded by FRDC over the period January 2012 to May 2016.

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 considered for valuation. Past and future cash flows were expressed in 2017/18 dollar terms and were discounted to the year 2017/18 using a discount rate of 5% to estimate the investment criteria.

Results/key findings

The investment has likely contributed to several impacts. Not all of the impacts were valued. Several economic, social and environmental impacts/potential impacts were identified. The impact valued was the improved social licence to operate for Tasmanian Atlantic salmon producers via improved reef assessments and environmental models.

Investment Criteria

Total funding from all sources for the project was $0.69 million (present value terms) with FRDC investment in the project totalling $0.07 million. The investment produced estimated total expected benefits of $2.28 million (present value terms). This gave a net present value of $1.60 million, an estimated benefit-cost ratio (BCR) of 3.32 to 1, an internal rate of return of 23.9% and a modified internal rate of return (MIRR) of 9.6%.

Conclusions

While several economic, environmental, and social impacts identified were not valued, such impacts were considered were potentially large but uncertain or likely to be minor in value compared with the impact valued. Nevertheless, combined with conservative assumptions for the impact valued, investment criteria as provided by the valuation may be underestimates of the actual performance of the investment.

Keywords

Impact assessment, cost-benefit analysis, aquaculture, nutrients, eutrophication, environmental monitoring, reef ecology, salmon farming

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, that included 20 randomly selected FRDC investments, was completed in August of 2017. The published reports for the first series of evaluations can be found at: http://frdc.com.au/Research/Benefits-of-research/2017-Portfolio-Assessment

The second series of impact assessments also included 20 randomly selected FRDC investments. The investments were worth a total of approximately $5.62 million (nominal FRDC investment) and were selected from an overall population of 96 FRDC investments worth an estimated $21.32 million (nominal FRDC investment) where a final deliverable had been submitted in the 2016/17 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 26% 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 2011-042: *TSGA IPA: clarifying the relationship between salmon farm nutrient loads and changes in macroalgal community structure/distribution (Existing Student Support*) was selected as one of the 20 investments and was analysed in this report.

General Method

The impact assessments 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. The approach includes 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. Where impact valuation was exercised, the impact assessment uses Cost-Benefit Analysis as its principal tool. 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 for individual investments potentially represent an underestimate of the performance of that investment.

Background and Rationale

Background

The Huon Estuary and D'Entrecasteaux Channel are major salmon aquaculture production areas. Farming is conducted in open water cages and as such waste and excess feed can be flushed into the surrounding environment. This may have the effect of increased nutrient loads within and around salmon production areas, potentially having negative environmental impacts. While the relationship between nutrient loads and the condition of benthic habitats in this system is quite well established, there is limited understanding of the effect of nutrient loads on macroalgal reef communities.

Rationale

Concerns were raised by local fishing industries that there may be adverse impacts on macroalgal reef communities from nutrient loads from salmon farming. The salmon industry was also keen to clarify both whether there was the potential for nutrients from farming to affect the algal communities on reefs, and to establish whether co-culture of macroalgae could be used to mitigate increases in nutrients in areas where salmon farming occurs. Having robust scientific data on the response of macroalgal communities to nutrients would help determine whether nutrient mitigation through increasing macroalgal communities is achievable. An Integrated Multi-Trophic Aquaculture (IMTA) system in which seaweed and kelp species are farmed around salmon pens to lower nitrogen concentrations may provide a solution, with added potential positive commercial outcomes for algal farming.

By utilising PhD students, there is an opportunity to undertake research at a lower cost than through conventional project funding. Luis Henriquez Antipa had ten years' experience in macroalgal ecology which made him a suitable candidate for the field based ecological impacts study while Scott Hadley had a strong mathematical background making him a very good candidate for the modelling study. Hence these two PhD students had the necessary experience to carry out the project. Scott Hadley's PhD explores the potential to mitigate nutrient loads via IMTA, while Luis Henriquez Antipa's PhD explored the effects of changing nutrient regimes on local macroalgal communities. The results of the PhDs should lead to a greater understanding of macroalgal communities and the effect of nutrient loads on those communities.

Project Details

Summary

Project Code: 2011-042
Title: TSGA IPA: clarifying the relationship between salmon farm nutrient loads and changes in macroalgal community structure/distribution (Existing Student Support)
Research Organisation: University of Tasmania
Principal Investigator: Catriona MacLeod
Period of Funding: January 2012 – May 2016
FRDC Program Allocation: Environment (80%), Industry (10%), Communities (10%)

Objectives

The project's key objectives were:

1. Clarify the effect of nutrient changes on key macroalgal species under a variety of different environmental conditions
2. Characterise macroalgal communities in potential "hotspots" and identify key species
3. Model nutrient changes in key "hotspot" areas under a variety of different natural and anthropogenic input scenarios
4. Examine the cost-benefit of alternative theoretical scenarios for nutrient mitigation

Logical Framework

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

Table 1: Logical Framework for Project 2011-042

Activities and Outputs	***PhD One – Luis Henriquez Antipa*** • In Luis Henriquez Antipa's study, an artificial nutrient source was added to three reef systems to assess the effects of increased nutrient availability on macroalgal community composition. • The research looked at the reef habitats in the D'Entrecasteaux Channel (Tasmania), assessing three locations - Tinderbox, Green Island, and Ninepin Point. • Sample plots were established at random within each location, with both control plots and treatment plots to understand the effect of nutrient loadings on community structure, dynamics and at the physiological level. • Data collected from each site included algal abundance, species diversity, community structure, water temperature, salinity and nutrient levels. The locations were compared across three time periods in Spring and Summer 2012. • Dissolved nutrients (nitrite, nitrate, ammonia and phosphorus) were added to the treatment plots after baseline data had been collected. The added nutrients at each site were equivalent to the feed required to produce 880 kg of Atlantic salmon. • Every three months evaluation took place of photosynthetic rates of each macroalgal species. • The research showed that macroalgal assemblages in the D'Entrecasteaux Channel are relatively resistant to increases in nutrient loads, but that some sites had a greater resilience than others.

	• Species from Tinderbox had higher levels of nitrogen and phosphorus compared to Green Island and Ninepin Point. • Opportunistic species (often indicative of nutrient enrichment) were observed, but the relationship between the prevalence of opportunistic species and nutrient loads within the Channel could not be confirmed. • It was concluded that the macroalgal community in the D'Entrecasteaux Channel is relatively robust to moderate inputs of nutrients. • The additional nutrients did not have a sustained effect on the community structure or abundance of macroalgal reef communities in any of the locations tested. • There were no differences between nutrient uptake in plant tissue at the control and treatment in spring, and nutrient loads in tissues were lowest in summer. • The research concluded that it is the combination of environmental factors along with nutrient loads, that results in any potential impact on macroalgal communities. Wave and light exposure had an important influence on nutrient conditions and as a result the potential for impacts on macroalgal composition. • The research recommended that the relationship between hydrodynamics and the inherent productivity and physiology of macroalgal reefs be explored further. ***PhD Two – Scott Hadley*** • For Scott Hadley's PhD, computer modelling was used to assess the feasibility of growing algae for IMTA in and around salmon farms in the D'Entrecasteaux Channel and Huon Estuary. • There was development of a three-dimensional ecosystem model of the regions using CSIRO's Environmental Modelling Suite (EMS). The CSIRO EMS was developed to enable the study of the coastal ecosystem of the D'Entrecasteaux Channel and the Huon Estuary. This PhD project used the CSIRO EMS to test different scenarios as a full-scale IMTA experiment would have been financially unfeasible. The research aimed to investigate the potential for IMTA to offset nutrient inputs from fish farming in a stylised system based on the D'Entrecasteaux Channel and the Huon Estuary under three different load scenarios, and to propose the most effective IMTA production strategy for this system. • Three scenarios of simulation of phytoplankton took place: no finfish aquaculture, low nutrient loads, and high nutrient loads (10 times higher than low). • The modelling tested several different seaweed species and suggested that while a number of seaweeds showed promise, kelp (*Macrocystis*) was found to be particularly useful in removing nutrients. The effectiveness of IMTA (associated with cages) was noted to be particularly dependent on flow rates near the salmon cages. • The research recognised that an additional benefit of IMTA is the potential to support conservation of "at risk" species such as the giant kelp Macrocystis. • The model findings showed that IMTA systems could reduce nutrient concentration, and the potential for eutrophication, around salmon production areas. • The research suggested that costs could be minimised through targeted placement of IMTA systems; the findings suggested that nitrogen (N) may not be contributing to negative impacts in some locations and that in certain locations IMTA systems did not contribute to N removal.
Outcomes	• Information generated by S. Hadley's PhD research can improve decisions on where to place salmon pens within the D'Entrecasteaux Channel and Huon Estuary. This provided insights into where best to place farms for minimum nutrient impact, and where to position IMTA systems to most effectively mitigate nutrient inputs caused by aquaculture activities.

	• The Institute of Marnie and Antarctic Studies (IMAS) submission to the Senate Environment and Communications References Committee Inquiry into Fin-fish Aquaculture in Tasmania (Macleod et al., 2015) and in the submission to the Marine Farming Planning Review Panel Independent Assessment of salmon farming at Okehampton Bay (Macleod et al., 2016) used the research from the two PhDs to inform the submissions. • The Tasmanian Atlantic salmon industry is actively exploring IMTA to improve environmental outcomes around aquaculture operations, with pilot farms in operation (Catriona Macleod pers. comm., 2018). • Luis Henriquez's PhD was integral to identifying regional differences in resilience and susceptibility of reef systems to nutrient inputs from salmon farming and has been an important precursor to the subsequent reef monitoring research in FRDC Project 2015-024 (Catriona MacLeod pers. comm., 2018). • Data included in the IMTA modelling have informed and improved the CSIRO biogeochemical modelling suite for the Huon River, Estuary and D'Entrecasteaux Channel as well as Storm Bay (Macleod et al., 2016). • The two PhDs have been instrumental in the development of additional research to establish an effective reef monitoring program for future salmon farming expansion in Storm Bay, and additional research looking specifically at the potential for interactions with reef systems and their effects on features of significance for abalone productivity (Catriona Macleod, pers. comm., 2018). • Both Luis Henriquez and Scott Hadley's PhD theses have improved the understanding of the variables used to measure nutrient loads within the D'Entrecasteaux Channel, which in turn have improved the approach to ecosystem modelling. • The modelled IMTA simulations are based on more realistic process assumptions and as such provided better predictions and an improved framework for future experiments and decision making. • The IMTA modelling and the reef assessments produced have helped industry and government make better environmental decisions around the location of salmon farm pens. • The two PhDs provided a clear understanding of the spatial risks associated with salmon farming operations in a marine system (Catriona MacLeod pers. comm., 2018). • There are now tools available, produced by the two PhD projects to undertake more useful risk assessments of reef systems. The salmon industry may use these to help improve aquaculture practices.
Impacts	• Improved social licence to salmon industry mainly focused on the D'Entrecasteaux Channel/Huon Estuary. • Increased research resource efficiency through PhD funding. • Potential improved environmental sustainability of the salmon industry in the D'Entrecasteaux Channel. • Increased profitability because of increased stocking rates due to an IMTA system. • Potential industry expansion due to reef modelling. • Increased scientific and research capacity.

Project Investment

Nominal Investment

Table 2 shows the annual investment (cash and in-kind) in project 2011-042 by FRDC and University of Tasmania.

Table 2: Annual Investment in the Project 2011-042 (nominal $)

Year ended 30 June	FRDC ($)	University of Tasmania ($)	Australian Government ($)	TOTAL ($)
2012	15,000	0	0	15,000
2013	12,000	71,092	54,164	137,256
2014	9,000	71,092	54,164	134,256
2015	4,500	71,092	54,164	129,756
2016	4,430	71,092	54,164	129,686
Totals	44,930	284,368	216,656	545,954

The project application or project documents did not include the in-kind costs of the PhD supervisors time and the cost of the PhDs. Table 2 assumes these costs. Primary supervisors in-kind are included at 10% of their assumed annual salary, while co-supervisors in-kind are included at 5% of their assumed annual salary. Luis Henriquez had one main supervisor and three co-supervisors, while Scott Hadley had one main supervisor and two co-supervisors. The Australian Government Research Training Program (RTP) Stipend is $27,082 per year (University of Tasmania, 2017). The costs in Table 2 include the RTP Stipend from 2013 for the cost of the PhD students.

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 (1.122). This multiplier was estimated based on the share of ‘employee benefits’ and ‘supplier’ expenses’ in total FRDC expenditure (5-year average) reported in the FRDC’s Cash Flow Statement (FRDC, 2013-2017). This multiplier then was applied to the nominal investment by FRDC shown in Table 2.

The program management and administration costs for the University of Tasmania and the other funders were assumed to be included in the nominal amounts 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 2017/18 dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2018).

Extension of the research findings was included as part of the project, with the PhD students being in constant communication with industry stakeholders throughout the project. There may be further extension costs for implementing some of the impacts. These costs are not included as these impacts are not valued.

Impacts

Table 3 provides a summary of the principal types of impacts expanded from those listed in Table 1 and categorised into economic, environmental and social impacts.

Table 3: Triple Bottom Line Categories of Principal Impacts from Project 2011-042

Economic	• Positive contribution to the social licence to operate for salmon pens in the D'Entrecasteaux Channel/Huon Estuary and other salmon locations around Tasmania. • Increased research efficiency through PhD funding. • Potential increase in profitability of the Tasmanian salmon industry due to the implementation of an IMTA system. • Potential industry expansion due to reef modelling.
Environmental	• Potential improved environmental sustainability of the salmon industry in the D'Entrecasteaux Channel.
Social	• Increased scientific and research capacity.

Public versus Private Impacts

The impacts produced by the project are both private and public impacts. While the majority of the impacts are private, there are significant public impacts such as improved environmental outcomes due to the improved nutrient modelling supported by the project. There will also be improved scientific research capacity in future abilities to research IMTA systems and reef assessments. Because of the project, there are research efficiencies leading to avoided larger research costs.

Distribution of Private Impacts

The main private impacts from the project will be captured by Tasmanian salmon producers. There is potential for greater confidence in maintaining or improving the social licence for salmon farming through the project providing better environmental information on reef monitoring and increasing confidence that salmon farming licensing decisions are based on the best information. There may also be an increased or maintained stock of production for salmon due to the improved modelling and potential implementation of an IMTA system.

Impacts on other Australian industries

There are expected to be no major impacts on other Australian industries. There may be some minor impacts to other Australian Atlantic salmon and aquaculture industries in other locations who can use the outputs produced.

Impacts Overseas

There is expected to be no significant impacts to overseas parties. There may be minor impacts to overseas salmon producers through increased scientific knowledge.

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 and 3, and to Science and Research Priority 1.

Table 4: 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

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

The only impact valued is an improvement in the status of the social licence for Tasmanian Atlantic salmon operators.

Impacts Not Valued

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

- The increased research efficiency though PhD funding compared to alternative funding.
- Potential increased profit to the Tasmanian Atlantic salmon farms through increased stocking because of the use of an IMTA system.
- Potential increase in profit to the Tasmanian Atlantic salmon industry through industry expansion due to reef modelling.

The increased research efficiency is not valued as reasonable assumptions cannot be made on the counterfactual on how much the research would have cost or how effective the research would be in the counterfactual scenario.

No reasonable assumptions could be made about the economic benefits of the implementation of an IMTA system leading to an increase in Atlantic salmon stocking rates (therefore increased profits). While there is sufficient evidence to suggest further research and development of IMTA systems is warranted, it is unknown whether IMTA systems will be viable for future use in salmon farming regions.

Increased profit through expansion of the Tasmania Atlantic salmon industry because of the reef modelling is not valued as the impact is highly speculative, with a high degree of uncertainty whether the outputs will be used to approve an increase in stocking rates. There needs to be further research before this is possible.

The environmental and social impacts not valued are:

- The improved environmental sustainability of areas around salmon pens.
- Increased scientific and research capacity

While the environmental and social impacts were significant, they could not be valued due to difficulty assigning a reasonable monetary value to such non-market impacts, lack of available data, and time and resource constraints.

Valuation of Impact: Improved social licence

The two PhD projects have improved the understanding of the spatial risks associated with salmon farming (Catriona Macleod, pers. comm., 2018). Through the reef model developed in Luis's PhD, can be used to improve planning, and understanding risk appropriate monitoring, the salmon industry can demonstrate that the salmon industry can use responsible farming practices without adversely affecting the surrounding environment. The potential to improve farming practices and the better environmental information to justify salmon farming will enhance the social licence, demonstrating that salmon farming is environmentally sustainable to take place within the farmed salmon regions.

As no regional breakdown of Tasmanian salmon production was readily available, the investment is assumed to affect the social licence of 40% of Tasmanian salmon gross value of production (GVP). For 2015/16, the GVP of the Tasmanian salmon industry is $704.4 million (ABARES, 2017). The project therefore could affect the security of $281.76 million of GVP for the Tasmanian salmon industry. While the Tasmanian salmon industry is expanding, the conservative value assumed is assumed constant. No reliable assumption can be made for the future growth of the industry although the Tasmanian salmon industry is aiming to be a $1 billion industry by 2030 (DPIPWE, 2016).

Because of the investment in the PhD research, the improvement to the social licence for salmon aquaculture in Tasmania is 1% of the affected GVP. Therefore, the two PhDs will improve the social licence by $2.82 million per year. The profitability from the gross value is assumed to be 10% of the GVP. The benefit each year will be $0.28 million. These benefits are assumed to last for ten years after the project completion with benefits ceasing in 2028.

While the project may enhance the social licence, allowing for the expansion of the Tasmanian Atlantic salmon industry, the analysis is assuming the GVP will remain constant for the Tasmanian salmon industry. Therefore, the benefit is that there is no lost production due to social licence pressure.

Specific assumptions for valuing the impact are provided in Table 5.

Counterfactual

While the project may have been funded at a future date, this is not assumed in the counterfactual. It is assumed that the benefits of the social licence to operate would have diminished before funding of similar research.

Over time the benefits from the project to the social licence may eventually become normalised. A cut off of benefits will occur in 2028. Table 5 provides specific assumptions.

Summary of Assumptions

A summary of key assumptions made for the valuation of the impacts is shown in Table 5.

Table 5: Summary of Assumptions

Variable	Assumption	Source
General		
Gross Value of Production of salmon industry	$704.4 million	ABARES, 2017
Profits as a percentage of GVP	10%	Agtrans Research
With Project 2011-042		
Proportion of salmon farms affected	40% of GVP	Agtrans Research
Amount of GVP potentially at risk	$281.76 million	$704.4 m * 40%
Percentage social licence impact saved due to investment	1%	Agtrans Research
GVP saved by the investment	$2.82 million	$281.76 * 1%
Profitability saved due to investment	$0.28 million	$2.82m * 10%
First year of benefit	2018	Agtrans Research
Last year of benefit	2027	Agtrans Research
FRDC Program Allocation		
Program - Environment	80%	FRDC
Program – Communities	10%	FRDC
Program – Industry	10%	FRDC

Results

All past and future costs and benefits were expressed in 2017/18 dollar terms using the Implicit Price Deflator for Gross Domestic Product. All costs and benefits were discounted to 2017/18 using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the Modified Internal Rate of Return (MIRR). The base analysis used the best available estimates for each variable, despite 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 (2016/17) as per the CRRDC Impact Assessment Guidelines (CRRDC, 2014).

Investment Criteria

Tables 6 and 7 show the investment criteria estimated for different periods of benefits for the total investment and the FRDC investment respectively. The present value of benefits (PVB) attributable to FRDC investment only, shown in Table 7, has been estimated by multiplying the total PVB by the FRDC proportion of real investment (9.17%).

Table 6: Investment Criteria for Total Investment in Project 2011-042

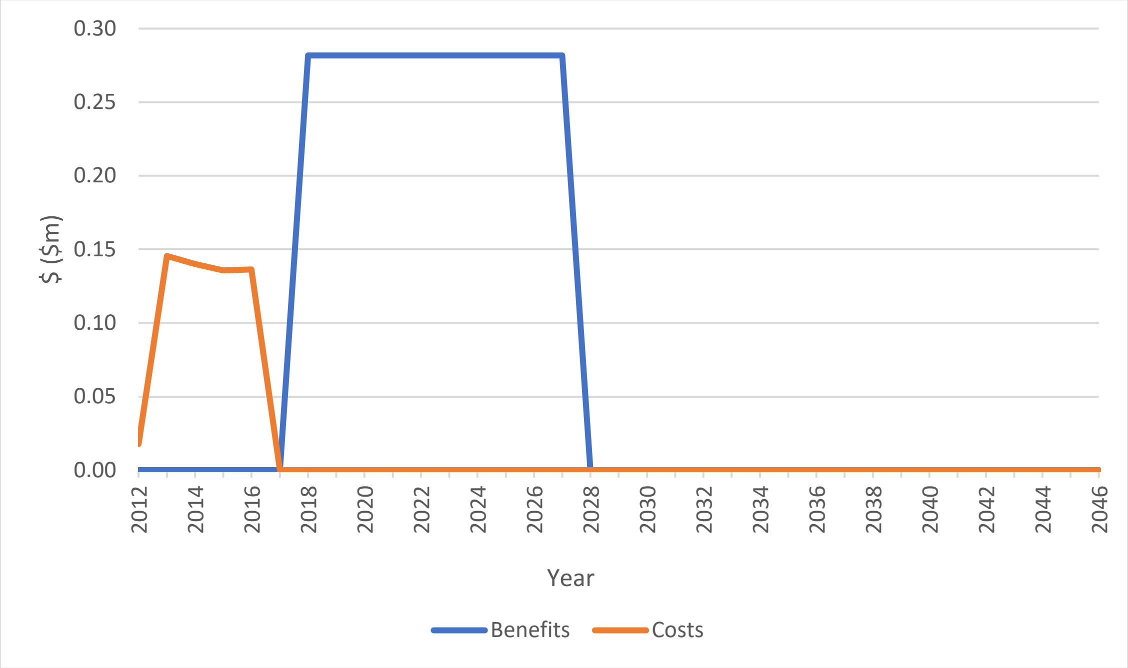
Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	1.05	2.10	2.28	2.28	2.28	2.28
Present Value of Costs ($m)	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Net Present Value ($m)	-0.69	0.36	1.42	1.60	1.60	1.60	1.60
Benefit-Cost Ratio	0.00	1.53	3.06	3.32	3.32	3.32	3.32
Internal Rate of Return (%)	negative	14.1	23.3	23.9	23.9	23.9	23.9
MIRR (%)	negative	20.9	20.7	15.2	12.3	10.6	9.6

Table 7: Investment Criteria for FRDC Investment in Project 2011-042

Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	0.10	0.19	0.21	0.21	0.21	0.21
Present Value of Costs ($m)	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Net Present Value ($m)	-0.07	0.03	0.13	0.14	0.14	0.14	0.14
Benefit-Cost Ratio	0.00	1.45	2.91	3.16	3.16	3.16	3.16
Internal Rate of Return (%)	negative	11.5	19.8	20.4	20.4	20.4	20.4
MIRR (%)	negative	18.9	20.0	17.7	11.9	10.4	9.4

The annual undiscounted benefit and cost cash flows for the total investment for the duration of the valued impacts from the FRDC project 2011-042 investment plus 30 years from the last year of investment is shown in Figure 1.

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



Sensitivity Analyses

A sensitivity analysis was carried out on the discount rate. 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. Table 8 presents the results. The results showed a moderate sensitivity to the discount rate.

Table 8: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($m)	2.82	2.28	1.90
Present value of costs ($m)	0.58	0.69	0.82
Net present value ($m)	2.24	1.60	1.09
Benefit-cost ratio	4.90	3.32	2.33

A sensitivity analysis was then undertaken for the assumption of the extent of the impact of the project on the social licence. This is the main variable driving the benefits from the investment. Results of this sensitivity analysis are reported in Table 9.

Table 9: Sensitivity to the Extent of Impact on the Social Licence
(Total investment, 30 years)

Investment Criteria	**Impact on Social Licence**		
	0.5% (pessimistic)	**1% (base)**	**1.5% (optimistic)**
Present value of benefits ($m)	1.14	2.28	3.43
Present value of costs ($m)	0.69	0.69	0.69
Net present value ($m)	0.46	1.60	2.74
Benefit-cost ratio	1.66	3.32	4.99

The results from Table 9 indicate that the investment criteria are sensitive to the social licence, with the benefit-cost ratio (BCR) moving by one in both the optimistic and pessimistic scenarios. The results indicate the project is robust over the range of values assumed, with the pessimistic scenario still having a BCR of 1.66.

A sensitivity analysis was undertaken on the assumption of the percentage of Tasmanian Atlantic salmon GVP affected by the improvement to the social licence generated by the project.

Table 10 Sensitivity to Percentage of Tasmanian Salmon GVP at Risk

Investment Criteria	**Impact on Percentage of Tasmanian Salmon GVP at risk**		
	20% (pessimistic)	**40% (base)**	**60% (optimistic)**
Present value of benefits ($m)	1.14	2.28	3.43
Present value of costs ($m)	0.69	0.69	0.69
Net present value ($m)	0.46	1.60	2.74
Benefit-cost ratio	1.66	3.32	4.99

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 11). 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 11: Confidence in Analysis of Project

Coverage of Benefits	Confidence in Assumptions
Low	Low

The coverage of benefits was assessed as low. While there was one benefit valued, the benefit valued only considers one impact for the investment, with five other impacts identified not being valued.

Confidence in the assumptions, used for valuation of the impact, was assessed as low as many of the assumptions were uncertain in nature. There is a clear pathway for the impact valued to affect the social licence through improved environmental information and modelling, but there is no direct evidence of the outputs of the project directly affecting the allowable production decisions through an improved social licence so far.

Conclusions

The investment in the student PhDs has likely resulted in an improved social licence for Tasmanian Atlantic salmon operators. The investment also has likely contributed to improved environmental sustainability via improved modelling ensuring that salmon farms are placed in appropriate locations that would not adversely affect the environment beyond acceptable levels.

Funding for the project totalled $0.69 million (present value terms) and produced estimated total expected benefits of $2.28 million (present value terms). This gave a net present value of $1.60 million, an estimated BCR of 3.32 to 1, an internal rate of return of 23.9% and a MIRR of 9.6%.

While several economic, environmental, and social impacts identified were not valued, the impacts were considered were highly speculative, although potentially large, uncertain and/or minor compared with the impact valued. Nevertheless, combined with conservative assumptions for the impact valued, investment criteria as provided by the valuation may be underestimates of the actual performance of the investment.

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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