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An Impact Assessment of FRDC Investment in Project: 2013-008: Movement, habitat utilisation and population status of the endangered Maugean skate

Agtrans Research

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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.

Researcher Contact Details
Name: Joseph Abell
Address: Suite 36, Benson House,
Toowong QLD 4066
Phone: 07 3870 4047
Fax: 07 3371 3381
Email: joseph@agtrans.com.au

FRDC Contact Details
Address: 25 Geils Court
Deakin ACT 2600
Phone: 02 6285 0400
Fax: 02 6285 0499
Email: frdc@frdc.com.au
Web: www.frdc.com.au

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

Contents

List of Tables

List of Figures

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Abbreviations

CRRDC	Council of Research and Development Corporations
DO	Dissolved Oxygen
DPIPWE	Department of Primary Industries, Parks, Water and Environment (Tasmania)
EPA	Environmental Protection Agency (Tasmania)
FRDC	Fisheries Research and Development Corporation
MFD	Maximum Follicle Diameter
MFPRP	Marine Farming Planning Review Panel
RD&E	Research, Development and Extension
TL	Total Length
TSGA	Tasmanian Salmon Growers Association
UTAS	University of Tasmania

Executive Summary

What the report is about

This report presents the results of an impact assessment of Fisheries Research and Development Corporation (FRDC) investment in a project to research the Maugean Skate and determine the potential effect of Atlantic Salmon escapees on the Maugean Skate. The project was funded by the FRDC over the three-year period July 2013 to February 2016.

Methodology

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

Results/key findings

Several impacts of the investment were identified of which one was valued. It is expected that the primary beneficiaries of the investment will be the Atlantic Salmon operators in Macquarie Harbour along with the general public.

Investment Criteria

Total funding from all sources for the project was $0.68 million (present value terms). The value of benefits was estimated at $6.37 million (present value terms). This gave an estimated net present value of $5.69 million, and a benefit-cost ratio of 9.4 to 1.

Conclusions

Overall, the project achieved its objective of providing new scientific knowledge of the biology, movements, and habitat of the Maugean Skate, aiding in its conservation, and assumptions when regulating Atlantic Salmon farming along with researching the movements and ecological impact of escaped Atlantic Salmon in Macquarie Harbour.

The increased knowledge associated with the Maugean Skate associated with its ongoing conservation was one of, if not the main impacts of the project. It is difficult to ascertain the size and value of this impact. The assumptions made in the analysis for valuing the impact of the project are based on conservative assumptions. The impacts not valued along with these conservative assumptions, make it likely that the benefits valued are underestimated.

Keywords

Impact Assessment, Maugean Skate, Zearaja maugeana, Macquarie Harbour, telemetry, gillnet bycatch, salmonid aquaculture, salmonid escapees.

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 2013-008: *Movement, habitat utilisation and population status of the endangered Maugean skate and implications for fishing and aquaculture operations in Macquarie Harbour* 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 Maugean Skate (*Zearaja maugeana*) was discovered scientifically in Tasmania in 1988. The Maugean Skate is part of the Rajidae family, related to other Zearaja species found in New Zealand and along the Pacific Coast of South America. The Maugean Skate is endemic to Macquarie Harbour and Bathurst Harbour in South-West Tasmania and is the only known estuarine species of Rajidae worldwide. In a previous study by Last and Gledhill (2007), there was an estimate of approximately 1,000 Maugean Skates in Macquarie Harbour, while the population in Bathurst Harbour was unknown.

Macquarie Harbour is currently a heavily trafficked area, with salmonid aquaculture operations taking place along with prevalent recreational gillnetting activity. Factors including heavy metal pollutants from past mining operations and a hydro-electric dam in the Gordon River have also affected the nutrient dynamics and thus ecology of the harbour. These human activities may influence the population dynamics of the Maugean Skate, but to what extent is unknown.

The Maugean Skate was put on the Tasmanian endangered list in 1995 (Threatened Species Section, 2017) and the Commonwealth endangered list on 2004 (Department of Environment and Energy, 2004) and updated in 2008 (Department of Environment and Energy, 2008) due to the factors above and the small distribution and number of the Maugean Skate (hereafter referred to in this report as Skate).

Rationale

Previously there have been no comprehensive studies of the Skate. There was little information available on their size, movement in the harbour, feeding regime, and reproductive status.

The Marine Farming Planning Review Panel (MFPRP) recognised that for Atlantic Salmon aquaculture to be able to expand, there needed to be evidence that Atlantic Salmon aquaculture poses no serious threat to the Skate. The effects of Atlantic Salmon aquaculture on the Skate needed to be further investigated to ensure no adverse impacts from aquaculture were imposed on this species, as interactions between the two species were largely unknown. It is therefore possible that Atlantic Salmon farming and Atlantic Salmon escapees may be having a direct or indirect impact on the Skate (through feeding or gillnetting).

Recreational and commercial gillnetting are commonplace in Macquarie Harbour. Gillnetting takes place to catch escaped Atlantic Salmon. A study from (Lyle, et al., 2014) has shown the Skate is a common bycatch from gillnetting in Macquarie Harbour, potentially causing harm to the Skate.

The study aimed to show the effects of Atlantic Salmon on the Skate and help determine whether Atlantic Salmon farming can continue to expand in Macquarie Harbour. Further investigation into Skate and Atlantic Salmon movement will help inform future gillnetting policy, as the potential interactions between the Skate and gillnetting will be defined with such information useful in forming policy to help preserve the Skate.

Project Details

Summary

Project Code: 2013-008 Title: *Movement, habitat utilisation and population status of the endangered Maugean skate and implications for fishing and aquaculture operations in Macquarie Harbour* Research Organisation: University of Tasmania (UTAS) Principal Investigator: Jeremy Lyle Period of Funding: July 2013 to February 2016

Objectives

The objectives of the project were:

1. To determine the distribution, habitat utilisation and movement of the Maugean Skate in
2. Macquarie Harbour;
3. To determine the key biological characteristics of Maugean Skate, including population size, reproductive dynamics and feeding habits;
4. To describe the spatial and temporal dispersal patterns of aquaculture escapees;
5. To assess the potential impacts of current and proposed marine farming operations on the
6. Maugean Skate population; and
7. To evaluate strategies to reduce the probability of encountering Maugean Skate whilst fishing (gillnetting) for escapees.

Logical Framework

Table 1 provides a description of the project in a logical framework developed for the evaluation.

Table 1: Logical Framework for Project 2013-008

Activities and Outputs	• Gillnets were placed around Macquarie Harbour at Liberty Point/Table Head, Swan Basin and Kelly's Basin/Rum Point to catch Maugean Skate for the study. Nets were retrieved within 3 hours being dropped to ensure the health of the Skate captured. • The captured Skate were then tagged for tracking the species' movement around the harbour. A number of Skate also were caught for reproduction and respiratory experiments, with seven female Skate euthanised for age and biological sampling. • Fifty-seven receivers were placed around the harbour to track the tagged Skate's movements. • The project team found that the Skate do not leave Macquarie Harbour and have high site loyalty with only a minority returning to new areas after capture. But further tracking was recommended as Skate do have the ability to move around the harbour. • Monitoring showed that the Skate in Macquarie Harbour have a preference for, and spend most (85%) of their time in, shallow water (6-12 metres) in benthic conditions, but were shown to have a range of depths between 0.6 metres and 50+ metres. The results also show the Skate's habitat did not cross over with the Atlantic Salmon pens.

	• Stomach flushing of the Skate was implemented to determine the Skate's diet. • It was found that the Skate diet consists mainly of epibenthic crustaceans, namely crabs, carid shrimp and mysids. No evidence was found that the Skate consume pellet feed from salmon aquaculture operations in the harbour. • A total of 30 Atlantic Salmon and 30 Rainbow Trout with trackers were released into Macquarie Harbour so that their movements and persistence within the estuary could be monitored. • The objective of the salmonid experiment was to understand dispersal and survival of escapees – noting that the companies have been required to re-capture escapees, so understanding how they move within the system would have implications for targeted netting effort (Jeremy Lyle, pers. comm., June 2017). • The project found that Atlantic Salmon and trout had a wide range of movement throughout the harbour, making efforts to try and catch after an escape event largely impractical. The reality is that the Atlantic Salmon disperse very quickly and sustained gillnet fishing around the farm site is likely to be relatively unproductive (Jeremy Lyle, pers. comm., June 2017). • A second aim of this component of the project was to better understand the impact of escapees on native fauna (i.e. as a predator). Some Atlantic Salmon and trout left the harbour or went upstream into rivers, while the majority died within the harbour earlier than their expected lifespan, with 1 in 4 escapees being recaptured by recreational fishers. The early deaths suggest that they have problems finding feed, as recaptured Atlantic Salmon were found to have no dietary items in the stomach. • The findings of the Atlantic Salmon and trout movement suggest that there may be no conflict between escaped Atlantic Salmon and trout and Skate for resources within the harbour. • Atlantic Salmon were confirmed not to be a predator in the harbour, due to the above findings. • The reproductive status of Skate was measured using non-disruptive techniques along with modelling the reproductive status of the Skate based on maximum follicle diameter (MFD) and total length (TL) (Bell, et al., 2016, p. 39). Using MFD, it was found that Skate are reproductively active all year round but less so in the summer. • No Skate were observed laying eggs when captured by researchers. The study did however find hatched eggs at depths of 20 meters and below. This finding was consistent with a previous study (Treloar, Barrett, & Edgar, 2013) showing live eggs at levels below 20 metres. It was suggested that decreasing Dissolved Oxygen (DO) levels below 20 metres may harm Skate reproduction (Bell, et al., 2016, p. 55) but further research was recommended on egg deposits and biology. • The project investigated the ecology of the Skate by designing an experiment to test tolerance to different DO levels. Skates were placed in tanks with 55% DO (typical DO level upon being caught) and 20% DO (consistent with low DO levels in the harbour). The experiment showed that at 20% DO level, the Skate switch to an anaerobic system, that can only be sustained temporarily. This suggests that Skate have a low tolerance to DO levels below 20% and cannot sustain being in low DO conditions for long. It was noted that consistently low DO environments can limit habitat range. • From the movement tracking, it also was found that the Skate changed their preferred depth range following a DO recharge event. The project found that Skate actively moved to higher DO environments. • It was estimated that there are approximately 3,000 Skate in Macquarie Harbour, but this may be an underestimate partly due to issues associated with gillnet mesh selectivity (juvenile and sub-adults were poorly represented in the samples) and model assumptions.

	• The project recommended that further research be carried out on the Skate to consider what effect DO levels have on them in Macquarie Harbour. • As gillnetting is set in at depths around 5m, it was noted that there is some crossover of the Skates' movements with gillnetting, but not as frequent as thought, as gillnetting is set mainly at night and in shallow water (<5 metres). • Some extension activities were carried out, with several talks to industry bodies explaining the research and a newspaper article was published in The Mercury newspaper.
Outcomes	• As the project was the first comprehensive independent study carried out on the Maugean Skate, the government regulator did not need to determine the impact of Atlantic Salmon escapees on the Skate in Macquarie Harbour or take precautionary action due to the project results. • The Maugean Skate biology, feeding, and population was comprehensively studied, allowing the government regulator not to take precautionary action in relation to Atlantic Salmon aquaculture. • The regulator may have concluded that Atlantic Salmon escapees do not have a significant impact on the ecology of the harbour or any impact on the Skate, so no further action was taken to ensure escapees were captured or lower Atlantic Salmon farming biomass. • The West Coast Recreational Fishers Association recommended a plan to reduce gillnetting in the areas where the Skate are found, and also suggested shorter soaking times. In November 2015, a change in regulation led to a reduction in gillnetting soak times in deep waters (over 5 m) and a closure on gillnetting in Liberty Point and Table Head to lessen the risk of Skate mortality as well as reduce gill netting interaction with recreational fishers. • A report (Ross & Macleod, 2017, p. 36) recommended that further population tracking should be carried out on the Skate because of the findings of Project 2013-008. • FRDC project 2016-068 has since been funded to further investigate the effects of DO levels on the Skate. This project is also addressing, egg biology as hatched Skate eggs were discovered to be deposited in deep waters (>20m) during the earlier project, where DO levels may be low. It is noted that Skate eggs are exposed to a low DO environment for a third of the time (Jeremy Lyle pers. comm., June 2017). This new project was funded because of the recommendations from Project 2013-008. • Potentially improved policies and conservation efforts can be made because of the project findings. The focus has moved away from Atlantic Salmon escapees and gill netting to other areas such as the effect of DO levels on the Skate.
Impacts	• Contribution to the maintenance of current Atlantic Salmon biomass production along with a lower probability of a future biomass reduction due to the increased knowledge of the Skate and Atlantic Salmon aquaculture relationship. • However, the project influenced a decision to lower Atlantic Salmon biomass due to the uncertainty of the lower DO levels on the Skate and the Skate eggs. • The project contributed to a lower probability of a conservation status change for the Skate from endangered to critically endangered. • Enhanced Skate welfare and increased probability of survival due to less time caught in gill nets. • Maintained social licence for the Atlantic Salmon industry and the recreational fishing sector to operate in Macquarie Harbour. • Increase in scientific knowledge and research capacity. • Maintained social spillovers from the continuing operation of aquaculture with maintained employment in regional Tasmania.

Project Investment

Nominal Investment

Table 2 shows the nominal annual investment made in Project 2013-008 by FRDC and UTAS, as well as others including Tasmanian Salmonid Growers Association (TSGA) and the Tasmanian Department of Primary Industry, Parks, Water and Environment (DPIPWE).

Table 2: Annual Investment in Project 2013-008 (nominal $)

Year ended 30 June	FRDC ($)	UTAS ($)	OTHER ($)	TOTAL ($)
2014	145,586	91,330	48,600	285,516
2015	25,003	117,295	25,000	167,298
2016	93,236	20,855	0	114,091
Totals	**263,825**	**229,480**	**73,600**	**569,905**

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’s 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 purposes of the investment analysis, the investment costs of all parties were expressed in 2016/17 $ terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2016). There are no extension costs associated with the project.

Impacts

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

Table 3: Triple Bottom Line Categories of Principal Impacts from the Maugean Skate research

Economic	• Maintained Atlantic Salmon biomass at current levels and avoided reduction because of Atlantic Salmon escapees and further information on the biology, habitat, population, and movement of the Maugean Skate. • Potential lower Atlantic Salmon biomass because of the Maugean Skate's reaction to low DO levels.
Environmental	• Lower probability of conservation downgrade of the Maugean Skate • Increased probability of Maugean Skate survival
Social	• Contribution to maintenance of social licence for Atlantic Salmon aquaculture and recreational fishing • Increased scientific knowledge and research capacity • Increased incomes to Macquarie Harbour community due to spillovers from sustainable Atlantic Salmon aquaculture industry and maintained harbour health. • Maintained social spillover to wider community

Public versus Private Impacts

The benefits identified in this analysis are both public and private impacts. The main public impact is improved research and knowledge on the Maugean Skate and the conservation actions allowing for a larger probability of its survival. There are significant public impacts through maintained recreational fishing value, social licences, and social spillovers to maintained regional incomes. The principal private impact is on Atlantic Salmon farming where the project contributed to both positive and negative economic impacts.

Distribution of Private Impacts

The majority of the private impacts will flow to the Atlantic Salmon industry, as they will capture any gains or losses from the maintained biomass as well as a potentially lowered biomass due to regulatory decisions emanating from the DO findings.

Impacts on other Australian industries

Other Australian industries are unlikely to be affected by the project.

Impacts Overseas

No significant benefits to overseas parties are expected.

Match with National Priorities

The Australian Government's Science and Research Priorities and Rural Research, Development and Extension (RD&E) priorities are reproduced in Table 4. The project will contribute primarily to Rural RD&E Priority 3 and to Science and Research Priority 2.

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.

The impact valued is the continuation of the current Atlantic Salmon biomass due to the project finding that Atlantic Salmon escapees had an insignificant impact on the ecosystem and the increased knowledge of Maugean Skate biology. In other words, while the biomass has been lowered for other reasons in 2017, it is assumed the reduction would have been greater if not for Project 2013-008.

Impacts not Valued

Not all impacts identified in Table 3 could be valued in the assessment. The environmental and social impacts were difficult to value for several reasons. These include time and resource constraints, difficulty placing a credible monetary value on the Maugean Skate existence and survival, and availability of baseline data.

For the economic impacts not valued, it is difficult to distinguish the role of the Maugean Skate and Project 2013-008 had on the May 2017 Environmental Protection Agency Tasmania (EPA) biomass decision. While the Skate was listed as a factor in the decision, there are numerous reasons independent of the Skate why the biomass limit dropped (EPA Tasmania, 2017). Without Project 2013-008, it is likely that other factors independent of the Skate would have required the biomass limit of Atlantic Salmon to decrease to the current level biomass level (such as the effect on the World Heritage Area). As such, the potential decreased biomass is not valued as the reduction would have occurred without Project 2013-008. This may change if there is new information on the Maugean Skate from the new FRDC Project 2016-068, but this is beyond this project analysis at the time of writing as the new project has just begun.

As the Maugean Skate is a unique species and is only subject to a limited habitat, it is difficult to put a credible monetary value on the existence, option, and use value of the Maugean Skate and its improved conservation.

The other environmental and social impacts were not valued due to a lack of baseline data and resources to undertake an accurate valuation.

Valuation of Impact 1: Maintained Atlantic Salmon Biomass

The impact valued is the maintained production of the biomass of Atlantic Salmon due to increased knowledge of the Maugean Skate’s biology, habitat, population, movement and Atlantic Salmon escapees not having negative effects on the Skate. The May 2017 biomass decision by the EPA had the information from Project 2013-008, allow it not to make precautionary assumptions regarding the Maugean Skate. From Table 5, the current biomass is 12,000 tonnes per year (EPA Tasmania, 2017) and the gross value of Atlantic Salmon is $13,150 per tonne (ABARES, 2016). An assumption that the profit percentage of 10% is made. This is a conservative assumption due to the unknown nature of the Atlantic Salmon companies fixed, tax, and variable costs. As the Atlantic Salmon biomass in Macquarie Harbour is highly uncertain, it is assumed that the current biomass allocation will remain constant into the future for this impact assessment. The project allowed Atlantic Salmon farming to be maintained at the level in the May 2017 biomass decision, due to Atlantic Salmon escapees not affecting the Skate. Specific assumptions for the benefit are listed in Table 5.

Counterfactual

Without the research into the Maugean Skate and Atlantic Salmon escapees effect on the Skate, the most likely outcome would have been a reduction in Atlantic Salmon biomass as the biology, population, movement and habitat of the Maugean Skate and effects of escaped Atlantic Salmon on the Skate and Macquarie Harbour would still be unknown.

The biology, population, movement, and habitat of the Maugean Skate would also be unknown, and the knowledge that there are few interactions between Atlantic Salmon and the Skate. Catch efforts to recapture the Atlantic Salmon would also result in increased gillnetting, harming the Skate.

Due to a precautionary principle approach that most likely would have occurred if the knowledge from the project was not produced. It is assumed that the Atlantic Salmon biomass would be 10% lower than the current biomass currently in place with a 50% probability that the reduction of 10% would have occurred.

Attribution

An attribution factor of 50% is assigned to this project as a result of FRDC Project 2010-016 on gillnetting first identifying the gillnetting effect on the Skate and highlighted the MFPRP recommendations. Along with the experience of the project team, the project teams experience can be assumed weighed significantly on the impact of the project.

As FRDC Project 2016-068 at the time of writing is getting underway, it is beyond this analysis to try and predict what the effect of this project will have on future biomass decisions as the harbour's environmental conditions are highly variable.

Summary of Assumptions

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

Table 5: Summary of Assumptions

Variable	Assumption	Source
Benefit: Avoided reduction in biomass		
Current farm gate value of Atlantic Salmon	$13,150 per tonne (t)	ABARES, 2016
Estimated percentage of profit per tonne of Atlantic Salmon	10%	Agtrans Research
Profit per tonne of Atlantic Salmon	$1,315	$13,150*10%
Macquarie Harbour maximum Atlantic Salmon biomass (without allowances)	12,000 t	EPA Tasmania, 2017
Counterfactual		
Percentage reduction of biomass without the project	10%	Agtrans Research
Probability of reduction of biomass	50%	Agtrans Research
Biomass without project	10,800 t	12,000 t*(1-.10)
Expected value of biomass	11,400 t	(50%*12000 t) + (12000 t*(1-10%)*50%)
Monetary value of benefit per year	$789,000	(12,000 t – 11,400 t) * $1,315
First year of impact	2017	Agtrans Research
Duration of impact	2047	Agtrans Research
Attribution	50%	Agtrans Research

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 (MIRR). 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 investment period plus 30 years from the last year of investment (2015/16) to the final year of benefits assumed.

Investment Criteria

Tables 6 and 7 show the investment criteria estimated for different periods of benefits for the total investment and FRDC investment respectively. The present value of benefits (PVB) attributable to the FRDC investment only, shown in Table 7, has been estimated by multiplying the total PVB by the FRDC proportion of real investment (49.27%).

Table 6: Investment Criteria for Total Investment in Project 2013-008

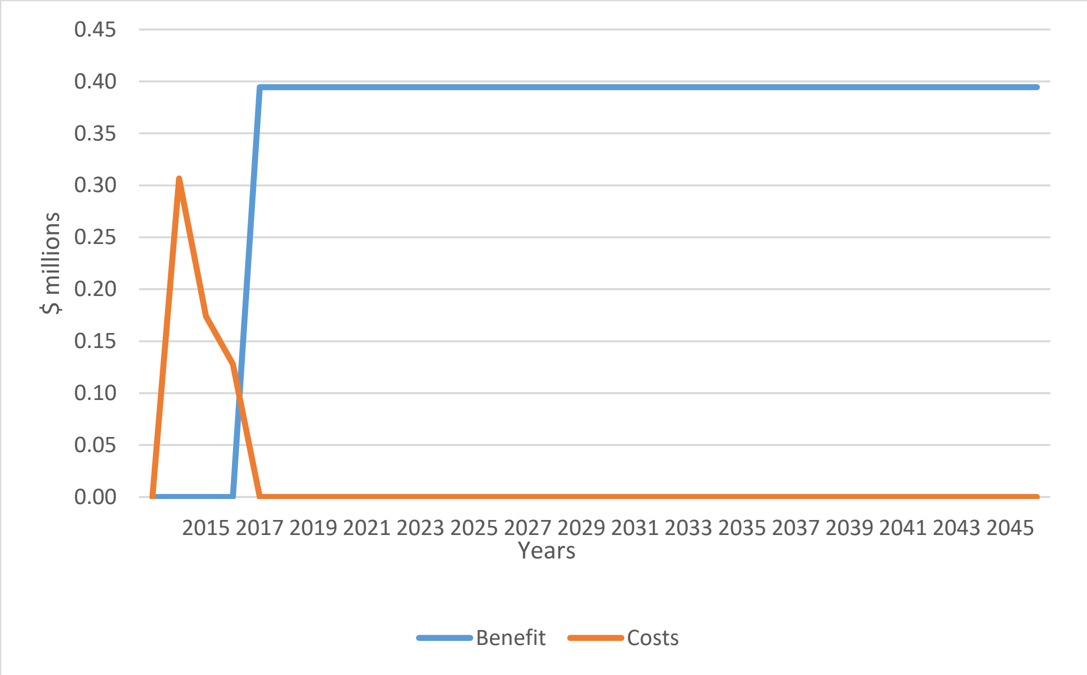
Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	1.79	3.20	4.30	5.16	5.84	6.37
Present value of costs ($m)	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Net present value ($m)	-0.68	1.11	2.52	3.62	4.48	5.16	5.69
Benefit-cost ratio	0.00	2.63	4.70	6.31	7.58	8.57	9.35
Internal rate of return (IRR) (%)	neg.	33.25	39.37	40.22	40.37	40.39	40.40
Modified IRR (%)	neg.	37.58	26.26	20.74	17.51	15.37	13.86

Table 7: Investment Criteria for FRDC Investment in Project 2013-008

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	0.88	1.58	2.12	2.54	2.88	3.14
Present value of costs ($m)	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Net present value ($m)	-0.33	0.55	1.24	1.78	2.21	2.54	2.80
Benefit-cost ratio	0.00	2.65	4.72	6.34	7.62	8.61	9.39
Internal rate of return (IRR) (%)	neg.	33.91	33.99	40.82	40.96	40.99	40.99
Modified IRR	neg.	33.91	24.75	19.81	16.84	14.86	13.43

The annual undiscounted benefit and cost cash flows for the total investment for the duration of investment period 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

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 moderately low 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 ($m)	11.84	6.37	4.09
Present value of costs ($m)	0.61	0.68	0.76
Net present value ($m)	11.23	5.69	3.33
Benefit-cost ratio	19.45	9.35	5.39

Pessimistic and Optimistic Scenarios

Sensitivity analyses were undertaken for pessimistic and optimistic levels of the variables with the highest level of uncertainty: the probability of a biomass reduction occurring and the percentage reduction of biomass. Results are reported in Table 9 and 10. The probability of biomass reduction and percentage of reduction of biomass pessimistic scenarios are well above breakeven.

Table 9: Sensitivity to Probability of Biomass Reduction
(Total Investment, 30 years)

Investment Criteria	Sensitivity to probability of biomass reduction		
	30%	**50%**	**70%**
Present value of benefits ($m)	3.82	6.37	8.91
Present value of costs ($m)	0.68	0.68	0.68
Net present value ($m)	3.14	5.69	8.23
Benefit-cost ratio	5.61	9.35	13.09

Table 10: Sensitivity to Percentage Reduction of Biomass
(Total Investment, 30 years)

Investment Criteria	Sensitivity to percentage reduction of biomass		
	5%	**10%**	**15%**
Present value of benefits ($m)	3.18	6.37	9.55
Present value of costs ($m)	0.68	0.68	0.68
Net present value ($m)	2.50	5.69	8.87
Benefit-cost ratio	4.68	9.35	14.03

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
Medium	Medium-Low

The coverage of benefits was assessed as Medium as the benefit valued addressed the most important impact, despite there being a number of other impacts identified.

The confidence in assumptions is rated as Medium-Low as, while the assumptions made are logical and indicative, they are not well supported by evidence.

Conclusions

Overall, the project achieved its objective of providing new scientific knowledge of the biology, movements, and habitat of the Maugean Skate, aiding in its conservation, and assumptions when regulating Atlantic Salmon farming along with researching the movements and ecological impact of escaped Atlantic Salmon in Macquarie Harbour.

Total funding for the project over the three years totalled $0.68 million (present value terms) and produced estimated total expected benefits of $6.37 million (present value terms). This gave a net present value of $5.69 million, a benefit-cost ratio of 9.35 to 1, an internal rate of return of 40.4% and a modified internal rate of return of 13.9%, discounted for 30 years.

It is not possible to capture all of the value of the research due to the non-market nature of some of the impacts. The increased knowledge associated with the Maugean Skate associated with its ongoing conservation was one of, if not the main impacts of the project. It is difficult to ascertain the size and value of this impact. The assumptions made in the analysis for valuing the impact of the project are based on conservative assumptions. The impacts not valued along with these conservative assumptions, make it likely that the benefits valued are underestimated.

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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