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An Impact Assessment of FRDC Investment in 2011-070: Comparative susceptibility and host responses of endemic fishes and salmonids affected by amoebic gill disease in Tasmania

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

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

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Mark Adams, Post-Doctoral Fellow, University of Tasmania

Abbreviations

ABS	Australian Bureau of Statistics
AGD	Amoebic Gill Disease
CRRDC	Council of Research and Development Corporations
DAWR	Department of Agriculture and Water Resources
FRDC	Fisheries Research and Development Corporation
OCS	Office of the Chief Scientist
RD&E	Research, Development and Extension

Executive Summary

What the report is about

This report presents the results of an impact assessment of the Fisheries Research and Development Corporation (FRDC) investment in a project investigating Amoebic Gill Disease (AGD) susceptibility in Atlantic salmon and Australian native fish.-The project was funded by FRDC over the five years ending 30th June 2012, 2013, 2014, 2015 and 2016.

Methodology

The investment in the project was analysed qualitatively within a logical framework that included activities/outputs, outcomes, and impacts. Identified impacts were then categorised into a triple bottom line framework. Principal impacts from those identified were considered for valuation.

Results/key findings

The project achieved its objectives of further researching native fish susceptibility to AGD. There was also increased scientific knowledge produced by the project. There were no impacts that could be valued impacts from the findings.

Investment Criteria

Funding for the project over the three years totalled $0.66 million in present value terms. The FRDC investment costs were $0.33 million in present value terms. No quantifiable benefits were produced from the investment.

Conclusions

Apart from scientific knowledge that may be used in the future, it is evident that the project did not produce any impacts that could be used directly by industry.

Keywords

Impact assessment, cost-benefit analysis, Atlantic salmon, amoebic gill disease, AGD, *Neoparamoeba*, yelloweye mullet, sand flathead, purple wrasse, Australian salmon, brown trout, rainbow trout, hybrid vigour.

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 2011-070*: Comparative susceptibility and host responses of endemic fishes and salmonids affected by amoebic gill disease in Tasmania* 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

Amoebic Gill Disease (AGD) is a significant health issue for the Tasmania salmon industry. First found in Tasmania in the 1980's, the disease has spread to the northern hemisphere and currently is the major issue for salmon aquaculture production.

AGD affects the culture of Atlantic salmon during the marine grow-out phase of production. The causative agent is *Neoparamoeba perurans* which when present upon the gills causes extensive proliferation of those tissues resulting in significant physiological disruption. Without treatment, AGD can lead to mortality in salmon stocks.

Currently, salmon are treated for AGD by freshwater bathing, killing AGD. The industry has recognised that freshwater bathing is not suitable in the long term due to costs and limited water resources. With the Tasmanian salmon industry wanting to expand production, and current sites almost at capacity, it is envisioned that new farming sites need to be established. New sites may not have the same ease of access to freshwater sources for bathing Atlantic salmon for AGD, so alternative treatment options are a priority for the industry.

Each salmon pen requires approximately 12 baths per salmon life cycle. AGD is estimated to cost the industry $1- $2 per kg of fresh salmon through extra bathing costs to kill the disease agent.

Rationale

The Tasmanian salmon industry has recognised that further research into AGD is needed as freshwater bathing is not sustainable with further salmon farming expansion.

There is a knowledge gap whether native species around salmon cages are susceptible to AGD and how hosts respond at gill level between susceptible and resistant salmon. By researching fish species resistant or tolerant of AGD, it was thought that insights could be gained towards a potential alternative treatment of AGD in Atlantic salmon.

There have been no previous studies under experimental conditions of differences in cellular responses between naïve fish and previously AGD infected salmonids, differences between salmonid species, and differences between salmonoids infected with *Neoparamoeba perurans* over multiple infections. By infecting native fish, Atlantic salmon and Trout species, with *Neoparamoeba perurans,* the causative agent of AGD, any insights can be recorded, and further knowledge gained, potentially allowing a development and testing pathway to future treatment options.

Project Details

Summary

Project Code: 2011-070 Title: *Comparative susceptibility and host responses of endemic fishes and salmonids affected by amoebic gill disease in Tasmania* Research Organisation: University of Tasmania Principal Investigator: Mark Adams Period of Funding: February 2012 – July 2016 FRDC Program Allocation: Industry (100%)

Objectives

The project included two key objectives:

1. To determine the susceptibility of sea-cage associated endemic fishes to Amoebic Gill Disease in comparison to Atlantic salmon
2. To investigate the comparative host responses of Atlantic salmon and rainbow trout naïve and previously exposed to Amoebic Gill Disease.

Logical Framework

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

Table 1: Logical Framework for Project 2011-070

Activities and Outputs	• Four native fish species (Australian salmon (*Arripidae*), yellow eye mullet, purple wrasse, and sand flathead) along with Atlantic salmon (*Salmonidae*), brown trout, and salmon-trout hybrids were exposed to *Neoparamoeba perurans* (hereafter *N. perurans*) to establish the cellular response to *N. perurans* between the different species. • Native fish were caught from three locations around existing Atlantic salmon cages in the Tamar River from March to June 2012. *Experiments one to four - AGD susceptibility trials for four endemic species with differing life histories* • In four experiments, native fish and Atlantic salmon were exposed to *N. perurans* and then tested for hyperplastic lesions colonised with *N. perurans.* A control group were tested and not exposed to *N. perurans* (the naïve group). Each experiment compared the response of *N. perurans* to the individual native fish species and Atlantic salmon. • For experiment one, 90% of Atlantic salmon and 65% of Australian salmon had hyperplastic lesions that tested positive for *N. perurans* after ten days of exposure to *N. perurans.* • In Atlantic salmon, 31.6% of hyperplastic lesions were positive for *N. perurans*, while only 13.3% of hyperplastic lesions in Australian salmon tested positive after ten days of exposure.

- For experiment two, 100% of Atlantic salmon and 30% of yellow eye mullet had hyperplastic lesions that tested positive for *N. perurans* after ten days of exposure to *N. perurans.*
- In Atlantic salmon, 56.2% of hyperplastic lesions were positive for *N. perurans*, while only 3% of hyperplastic lesions in yellow eye mullet tested positive after ten days of exposure.
- For experiment three, 100% of Atlantic salmon and 60% of purple wrasse had hyperplastic lesions that tested positive for *N. perurans* after ten days of exposure to *N. perurans*. In Atlantic salmon, 42% of hyperplastic lesions were positive for *N. perurans*, while only 15.2% of hyperplastic lesions in purple wrasse tested positive after ten days of exposure.
- For experiment four, 100% of Atlantic salmon and 63% of sand flathead had hyperplastic lesions that tested positive to *N.* perurans after ten days of exposure to *N. perurans.*
- In Atlantic salmon, 88.4% of hyperplastic lesions were positive for *N. perurans,* while only 30.8% of hyperplastic lesions in sand flathead tested positive for *N. perurans* after ten days of exposure.
- Across all of the experiments 1 to 4, Atlantic salmon were more predisposed to infection with *N. perurans*

Experiment five - Comparative sequential pathology of yellow-eye mullet (Aldrichetta forsteri) and Atlantic salmon (Salmo salar) during experimental challenge with N. perurans

- In an additional experiment, naïve to AGD Atlantic salmon and yellow eye mullet were co-habituated in two separate tanks. The naïve Atlantic salmon were from the same cohort as in experiments one to four. The project exposed ten Atlantic salmon and ten yellow eye mullets from one group to *N. perurans.* Samples were collected three, seven, 14, and 28 days after exposure, with an extra sample after 21 days exclusively for yellow eye mullet. Each system added an additional ten naïve Atlantic salmon after 14 days.
- An analysis was undertaken to understand the relationship between AGD severity and length of the interbranchial lymphoid tissue in infected Atlantic salmon and yellow eye mullet.
- In experiment five, yellow eye mullet and Atlantic salmon, both exposed to *N. perurans,* had hyperplastic lesions. The naïve cohort of each species had no unusual pathological findings.
- There were no significant differences between yellow eye mullet and Atlantic salmon for the percentage of filaments with hyperplastic lesions on days three, seven and 14. Atlantic salmon had a higher percentage of lesions colonised by *N. perurans* before day 21. Yellow eye mullet was not found to have *N. perurans* on days 21 and 28 despite having 40% of the yellow eye mullet infected with *N. perurans* on day 14.
- Yellow eye mullet, therefore, was found to resolve pathological signs of AGD under experimental conditions.
- Atlantic salmon had a higher percentage of hyperplastic lesions on day 28 compared to day 14. *N. perurans* colonised a lower percentage of lesions on day 28 compared to day 14.
- For naïve Atlantic salmon introduced on day 14. There were rapid signs of AGD appearing suggesting smaller fish were more susceptible to AGD.
- Epithelial hyperplasia altered the size and morphology of interbranchial lymphoid tissue in the gills of Atlantic salmon.

	Experiment six - Comparative pathology of AGD in Atlantic salmon (Salmo salar) and rainbow trout (Oncorhynchus mykiss) following repeated infections with Neoparamoeba perurans • For experiment six, there were comparisons between host responses of Atlantic salmon and rainbow trout naïve to AGD. • The rainbow trout and Atlantic salmon were split into two tanks co-habituating together, with one-month holding. Rainbow trout were withdrawn from the trial due to problems adjusting to full strength seawater. • Atlantic salmon were bathed in fresh water three times to kill *N. perurans* and exposed to *N. perurans* four times. • Under first exposure to *N. perurans*, tests were conducted for AGD on fish, and the severity was recorded. All fish were then bathed in freshwater (to kill AGD), with tanks drained and refilled. • Atlantic salmon were recorded as either having clear, light, moderate or heavy AGD severity based on observable hyperplastic lesions and lesion size and coverage on affected tissue. • For the final exposure, Atlantic salmon returned to the tanks without additional gill isolated amoebae. After one month, all fish were exposed to *N. perurans* then checked one week later. • There were no significant differences between the light, moderate and naïve groups for amoebic lesion colonisation following exposure to *N. perurans* for Atlantic salmon. *Experiment seven - Comparative pathology of experimentally induced AGD in pure and hybrid Atlantic salmon (Salmo salar) and brown trout (Salmo trutta)* • For experiment seven, researchers conducted tests on the different pathology of a hybrid mix of Atlantic salmon and brown trout (male-female, female-male, all combinations). Samples of some fish were collected after 18 days of exposure to *N. perurans*. • The presence of hyperplastic lesions and lesions colonised by amoebae was found to be significantly higher for Atlantic salmon when compared to salmon-trout hybrids. *Summary of outputs* • The project found that yellow eye mullet showed no signs of AGD and, despite having some signs of disease, hybrid gill surfaces may not be suitable for infection by *N. perurans.* • The project also found that other fish species can naturally resist and defend themselves against *N. perurans.* • The project was unable to identify genes that drive the emergence of AGD resistance in Atlantic salmon. • Yellow eye mullet and hybrid salmon-brown trout were recommended to be used for further research to understand how fish react to, and defend against, AGD. • The project recommended that further research be undertaken associated with: o Characterising the pathobiology and primary interactions of *N. perurans* with gill tissues. o Elucidating the functional properties of mucosal constituents responding to infection. o Immuno-pathological studies combining microscopic, genomic and proteomic approaches. o The impact of the host age and development upon reactivity to amoebic infection.

	◦ Further exploration, diversification and revision of AGD challenge and sampling methodologies. • There were two peer-reviewed scientific papers published from research conducted in this project • Results presented at two international conferences.
Outcomes	• Due to the increased knowledge of native fish and hybrid salmon/trout host susceptibility to *N. perurans,* future AGD research priorities could be better targeted in the future. • CSIRO has conducted further research into salmon-trout hybrids, for which the project may contribute scientific knowledge. • There has been no change in commercial Atlantic salmon production due to the project, as there have been no surprising findings in terms of native fish susceptibility to ADG (Mark Adams, pers. comm., 2018).
Impacts	• Potential for improved efficiency and efficacy of future AGD research. • Improved scientific and research capacity.

The project was a fundamental study in nature, so no industry outcomes or impacts came from the project. The Tasmanian Atlantic salmon industry has not used the outputs from the project for any production decisions.

There may be improved research targeting and outcomes into the future because of the project exploring native fish susceptibility to *N. perurans.*

Project Investment

Nominal Investment

Table 2 shows the annual investment made in Project 2011-070 by FRDC, the University of Tasmania, Van Dieman Aquaculture, and the Tasmanian salmon industry.

Table 2: Annual Investment in Project 2011-070 (nominal $)

Year ended 30 June	FRDC ($)	University of Tasmania	OTHER ($)	TOTAL ($)
2012	45,471	119,461	8,350	173,282
2013	69,365	101,354	12,800	183,519
2014	35,685	0	0	35,685
2015	54,100	0	0	54,100
2016	22,736	0	0	22,736
Totals	**227,357**	**220,815**	**21,150**	**469,322**

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 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 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). No additional costs of industry extension were included as there was no substantive industry impact of the project.

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 2011-070

Economic	• Improved research efficiency and efficacy for future AGD research.
Environmental	N/A
Social	• Increased scientific and research capacity.

Public versus Private Impacts

There is a mix between private and public impacts. For private impacts, the direct beneficiaries of this project potentially would have been to salmon researchers researching AGD. There are public impacts through increased scientific and research capacity.

Distribution of Private Impacts

Private benefits will be captured by salmon disease researchers, as there is an increase in knowledge of AGD. There may be potential future impacts to salmon producers who may potentially use future research findings.

Impacts on other Australian Industries

It is assumed that there will not be any impacts on other Australian industries.

Impacts Overseas

There may be impacts on overseas Atlantic salmon producers with some contribution to improved scientific research into AGD.

Match with National Priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 4. If potential impacts had been delivered, the impacts would have contributed to Rural RD&E Priorities 1, 2, and 3, and to Science and Research Priorities 1 and 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 (2016)

Valuation of Impacts

Impacts Valued

The project did not produce any quantifiable impacts, so no quantitative evaluation processes were applied to value benefits.

Impacts not Valued

The impacts identified in Table 3 were not valued for the following reasons (Table 5):

Table 5: Reasons for Not Valuing Impacts

Impact/Potential Impact	**Reason why Impact Not Valued**
Potential for improved efficiency and efficacy of future AGD research.	The difficulty of placing a financial value on any contribution to future research.
Improved scientific and research capacity.	The difficulty of placing a financial value on any contribution.

Results

All past costs were discounted to 2017/18 using a discount rate of 5%. All analyses ran for the length of the project investment period plus 30 years from the last year of investment in Project 2011-070 (2015/16).

Investment Criteria

Tables 6 and 7 show the investment criteria estimated for different periods of benefits and costs for the total investment and FRDC investment respectively. Note that, as no impacts were valued, the investment criteria reporting is restricted to the Present Value of Costs.

In the interests of consistency with other project analyses and reporting, the Present Value of Costs was reported for the length of the investment period plus for different periods up to 30 years from the last year of investment (2015/16).

Table 6: Investment Criteria for Total Investment in Project 2011-070

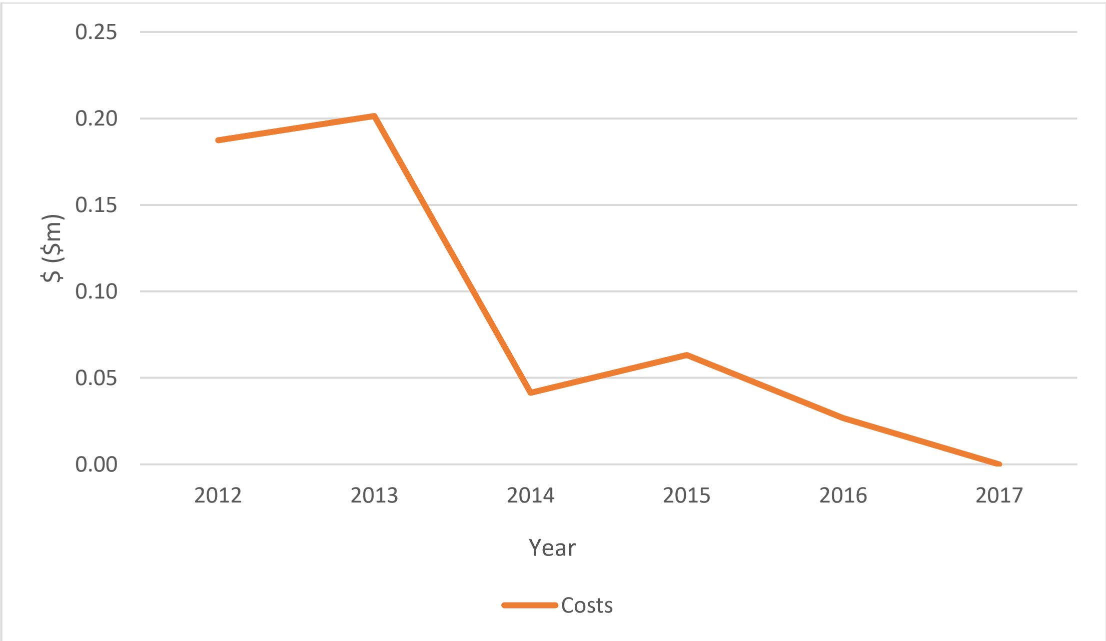
Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of costs ($m)	0.66	0.66	0.66	0.66	0.66	0.66	0.66

Table 7: Investment Criteria for FRDC Investment in Project 2011-070

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of costs ($m)	0.33	0.33	0.33	0.33	0.33	0.33	0.33

The annual undiscounted cost cash flow for the total investment for the duration of the investment period is shown in Figure 1.

Figure 1: Annual Cash Flow of Undiscounted Total Costs



Conclusions

Total funding for the investment over the five years totalled $0.66 million in present value terms. The FRDC investment costs were $0.33 million in present value terms. Apart from scientific knowledge that may be used in the future, it is evident that the project did not produce any industry impacts.

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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