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RESEARCH IMPACT EVALUATION

Atlantic Salmon Breeding Case Study

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Contents

1 Executive Summary

The Challenge

The Atlantic Salmon farming industry in Australia is growing, and currently valued at $500 million per year. The vast majority of salmon farming is located in Tasmania, where waters are the warmest in the world for Atlantic salmon culture. Warmer temperatures mean that Tasmanian Atlantic salmon can grow to a harvestable size within 16-18 months - a faster rate of growth than in other salmon producing areas of the world. However, faster growth comes at a cost: early maturation of fish degrades flesh quality, leading to a loss in market value, and increased susceptibility to disease which can result in significant stock losses.

The Tasmanian industry was also faced with issues including a closed population and therefore a need to manage genetic diversity, and biosecurity restrictions on movement of potential broodstock from the sea back to freshwater hatcheries. There was a need to manage key commercial traits, including growth rates and disease resistance, to further expand the salmon breeding industry.

The Response

In a joint project with Salmon Enterprises of Tasmania (SALTAS), CSIRO commenced a seven year project to establish a family- based selective breeding program in 2004. The selective breeding program focused on key performance traits in Tasmania's Atlantic salmon stocks, including increasing seawater growth; increasing resistance to disease; decreasing early maturation in seawater; and maintaining fillet colour and oil content.

CSIRO examines the performance of the fish, selecting individuals from which to breed the next generation to ensure the best overall outcome for growers. Three age groups of fish are being grown simultaneously and about 180 salmon families (4000-5000 pedigreed individuals) are being produced each year.

The Impact

The partnership is delivering tens of thousands of pedigreed Atlantic salmon with performance records and estimates of their genetic values for key commercial traits. Salmon from the breeding program demonstrated greater than 10 per cent gains in growth in each generation, which equates to production efficiencies worth millions of dollars each year.

Increased disease resistance is leading to both reduced costs for growers and reduced water consumption from fewer treatments of diseased fish. Based on conservative assumptions, the net present value (NPV) of the Salmon Breeding Program is approximately $169.3 million with $78.6 million attributable to CSIRO. The benefit-cost ratio (BCR) for CSIRO is approximately 27.

This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework to Salmon Breeding Program case study are summarised in Figure 1.

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACT
• CSIRO investment (FTE, in-kind contributions, equipment/facilities and background IP) • SALTAS investment (cash and in-kind contributions)	• Designing a cost effective operational plan for the breeding program • Analysing performance data and selecting fish from which to create the next generation • Developing systems and software for data management and analysis.	• First genetically improved salmon families selected for commercial traits such as weight, AGD resistance, fat and colour • An information system to capture, store and process pedigree and performance data. • Publications • Awards	***Uptake and Adoption*** • Adoption by salmon farmers with the ongoing capacity to select salmon broodstock to support industry growth • First commercial production from selected broodstocks • Strategic knowledge for other aquaculture breeding programs.	***Economic impact*** • Increased volume of catch • Reduced treatment costs of Amoebic Gill Disease and reduced losses. ***Environmental impact*** • Reduced water consumption. ***Social impact*** • Increased resilience of regional communities

Figure 1: Impact Pathway for the Atlantic Salmon Breeding Program

2 Purpose and Audience

This evaluation is being undertaken to demonstrate to a range of stakeholders the positive impacts arising from CSIRO's work on SALTAS's salmon breeding program (SBP). It is intended to assist Members of Parliament, Government Departments, CSIRO and the general public to understand the value of CSIRO and its contribution to Australia's innovation system.

This case study is proposed for accountability, reporting, communication and continual improvement purposes. Audiences for this report may include members of Parliament, Commonwealth Departments, CSIRO and the general public.

3 Background

Salmon Quarantine Policy

Imports of fresh and frozen salmon have been effectively banned in Australia under the Quarantine Act since 1975. In January 1995, Canada, later joined by the United States, requested

GATT (now World Trade Organisation) consultations with Australia on the quarantine restrictions applying to Australia's salmon imports. In response to WTO's decision, the Australian Government decided to relax the import restrictions on salmon in 1999. As a result, salmon product that is "consumer-ready" can now be imported into Australia (with the exception of Tasmania) and released from quarantine.

History

Atlantic salmon were first introduced to Australia in the 1800s, for the purpose of populating rivers in Tasmania and New South Wales for sport fishing. However, it was not until the 1960s, upon imports from the east coast of Canada to the Snowy Mountains in NSW, that Atlantic salmon populations became established. From 1984 to 1986, fertilized eggs were transferred from the Snowy Mountains to a quarantine hatchery near Hobart, and used as the founding stock of a salmon farming industry in Tasmania.

Atlantic salmon sea farming began with considerable encouragement from the Tasmanian Government. The industry is based almost entirely in Tasmania (98 per cent), with small quantities produced in Victoria and New South Wales (2 per cent) in land based ponds. Production of Atlantic salmon in Tasmania began later than in most major salmon farming countries but has grown quickly over the last 20 years. Annual production of Salmonids has increased from 1,750 tonnes in 1989-90 to 41,846 tonnes in 2013-14 (ABARES 2014).[1] Today, Atlantic salmon is the highest valued commercial fishery in Tasmania, with annual output valued at around $497 million (ABARES 2014). Sales of Tasmanian salmon are primarily into the domestic market, with mainland 'interstate' sales accounting for over 95 percent of total production (Tasmanian Salmonid Growers Association 2014). The Australian Atlantic salmon industry is still small on a world scale, accounting for around 2 percent of world farmed salmon production (Food and Agriculture Organization 2012).

Of the overseas sales, in excess of 98 percent are exported fresh or chilled whole, with three markets accounting for 75 percent of 2011-12 exports – China (44 percent), Japan (18 percent) and Vietnam (13 percent). Australia's free trade agreement with China may give a further boost to the salmon industry as it would remove the 12 percent tariff on salmon sold to China.

Production Systems

Salmon are hatched in freshwater facilities. After 12-18 months the young salmon undergo smoltification (becoming smolts), after which they can survive in saltwater. The smolts are then transferred to sea farms where they are grown in sea cages located in estuaries and coastal inlets. In Tasmania, these are located in the south-east, particularly the D'Entrecasteaux Channel, the Huon River system and the Tasman Peninsula, and in Macquarie Harbour on the west coast.

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[1] Includes salmon and trout production.

At 11-20 °C Tasmanian waters are the warmest in the world for Atlantic salmon culture. Because of relatively warmer waters, Tasmanian Atlantic salmon can grow to a harvestable size of up to 4.5 kg within 16-18 months after introduction to saltwater. This is a faster rate of growth than is achieved in other salmon producing areas around the world. However, the faster growth comes at a cost, as warmer waters may cause the fish stress and lead to an increase in disease susceptibility.

The higher water temperatures and other environmental factors lead to:

- Early maturation of fish in seawater which results in significant degradation of flesh quality and a subsequent loss in market value. The industry overcomes this production bottleneck by producing all-female stocks.
- Impaired growth and high rates of fish mortality as a result of Amoebic Gill Disease (AGD). The gill amoeba is a microscopic, single-celled organism that attaches to the gills, clogging them and preventing the flow of oxygen (CSIRO 2006). This can have a serious effect on the health and growth rate of the salmon, and if left untreated can result in stock losses of up to 80-90 percent over the summer months (O'Sullivan 2011).

Selective Breeding

Several factors led to the need for the Tasmanian industry to develop a selective breeding program:

- a closed population with no likelihood of further imports to enhance the genetic pool (need to manage genetic diversity and inbreeding);
- biosecurity restrictions on movement of potential broodstock from the sea back to freshwater hatcheries (therefore no direct commercial trait measures on potential broodstock);
- all-female production protocols; and
- impact of AGD increasing and not being reduced by other mitigation measures.

In response, following several years of pilot research and scoping studies, CSIRO through the Food Futures Flagship, collaborated with Salmon Enterprises of Tasmania Pty. Ltd. (SALTAS) and commenced a seven year R&D co-investment project to establish a family- based selective breeding program in 2004. The selective breeding program focused on the following key performance traits in Tasmania's Atlantic salmon stocks:

- increasing seawater growth;
- increasing resistance to AGD (measured through increasing time interval between freshwater baths);
- decreasing early maturation in seawater; and
- maintaining fillet colour and oil content.

4 Impact Pathway

Inputs

The following table shows the annual investment by SALTAS and CSIRO to the collaborative research agreement.

Table 1: Investment by SALTAS and CSIRO for Years ending June 2005 to June 2012 (nominal $)

Year	SALTAS	CSIRO	Total
2005/2006	$247,300	$200,000	$447,300
2006/2007	$300,000	$200,000	$500,000
2007/2008	$300,000	$250,000	$550,000
2008/2009	$340,000	$250,000	$590,000
2009/2010	$340,000	$253,000	$593,000
2010/2011	$326,000	$218,000	$544,000
2011/2012	$341,000	$228,000	$569,000
Total	**$2,194,300**	**$1,599,000**	**$3,793,300**

Source: CSIRO

In-kind contributions from SALTAS in terms of hatchery and marine site infrastructure and staff were significant, but are difficult to quantify as external input due to commercial confidentiality (estimated at approximately $0.5 million per annum). For example, the agreement with SALTAS and arrangements between SALTAS and Tassal Group Ltd provided access to breeding facilities and sea cages, without which the research could not have been undertaken.

Activities

Cost effective program design

Traditional aquaculture selective breeding programs are expensive because they raise families in separate tanks until the individuals grow large enough to be tagged and mixed. To avoid the initial capital costs of establishing such facilities, CSIRO designed the Tasmanian program to use a novel approach of combining families prior to hatching and subsequently using DNA genotyping to permit pedigree reconstruction. This enabled mixed family growout in a uniform environment.

The Tasmanian program was designed to initially revolve around a three-year cycle, which included spawning, tagging and DNA fingerprinting, monitoring procedures in freshwater and seawater, and parent selection. Three groups of fish were being grown simultaneously and about 180 salmon families (5000 to 7000 pedigreed individuals) were produced each year. In addition, elite individuals were selected to produce the commercial production broodstock.

The operational plan involved freshwater spawning and nursery, with tagging and DNA fingerprinting of the smolts at 12 months of age, followed by establishment of groups for either freshwater growout and broodstock conditioning, or performance testing during a marine growout. The marine fish were transferred to purpose-built sea cages at a Tassal Group Ltd Marine farm south of Hobart, where they were raised for a further 14 months to harvest sizes.

The salmon were assessed for AGD three to five times during the marine growout by inspecting the gills for lesions. The development of sexual maturation was measured in both the freshwater and marine groups. At about 4.5 kg, the marine group fish were harvested, weighted and assessed for carcass quality.

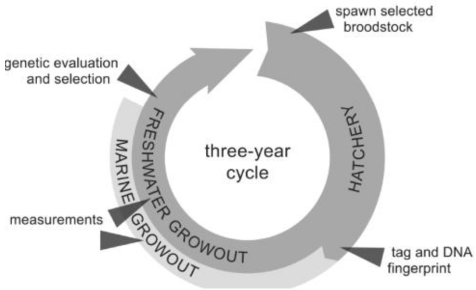

Figure 2: SBP year-class production cycle. Source: Elliott and Kube 2009

Analysing performance to choose the next generation

CSIRO developed a SALTAS-specific data base to store the thousands of records gathered and to manage the deep pedigree developed in the program. In addition, CSIRO developed systems and software for rapid and accurate collection of the thousands of phenotype data records. CSIRO analysed the performance of individuals, siblings, parents and more distant relatives to calculate 'estimate breeding values' for the key performance traits and determine which fish to use to breed the next generation. An economic weighting was given to each selection trait to achieve the best overall outcome for salmon farmers. Economic weighting is a weighting given to each trait in an index to indicate its relative economic importance compared to the other traits in the index. Index selection assumes linearity of profit versus trait value (within the scope of possible medium term genetic change). Alternatively, optimal responses could be manipulated by a 'desired gains approach'. This approach works well if knowledge about economic weight is not clear or if industry partners wish to maintain a level of confidentiality with regard to economic data, as was the case here. Each year the performance of all the fish were analysed. CSIRO also developed specific software tools for mate allocation and inbreeding management.

Outputs

In 2008, the program produced the first genetically selected families with performance records and estimates of their genetic values for key commercial traits such as weight, AGD resistance, maturation, fat and colour.

The project has also developed an information system for capturing, storing and processing hundreds of thousands of pedigree and performance measurements, as well as protocols and tools for tagging and genotyping.

Outcomes

The program has been successfully adopted and commercialised by SALTAS and Tassal with the first commercial production from selected multiplier broodstock achieved in 2011. Salmon from the breeding program demonstrated greater than 10 per cent gains in growth in each generation. This increase in growth equates to production efficiencies worth millions of dollars each year. Treatment of AGD is costly and labour intensive. AGD costs the Tasmanian salmon industry approximately 10% of the gross value of production (combination of lost productivity and treatment costs). The project results lowered AGD treatment costs by reducing the frequency of AGD treatment required.

It is conservatively estimated that fish generated using broodstock from the breeding program currently represent approximately 60 percent of salmon farmed in Australia. The adoption of broodstock from the breeding program by other salmon farmers such as Huon and Petuna through their shareholding in SALTAS is expected to continue to increase.

CSIRO's research has the potential to help global salmon production as AGD is now emerging as a significant health issue in commercial salmon populations in Scotland, Ireland and Norway as seawater temperatures increase.

Impacts

The selective breeding program has been successfully commercialised with its first commercial production commenced in 2009. The program has provided salmon farming companies with the ongoing capacity to select salmon broodstock to underpin the long-term success of the industry.

Strategic knowledge has been produced that can be used by CSIRO in other aquaculture breeding programs for improving the long-term efficiency of aquaculture. For example, the expertise that CSIRO has gained from the project is being applied both domestically and internationally in oyster, abalone and prawn breeding programs.

The SBP project has led to a variety of delivered and potential impacts, including increased production efficiency, reduced AGD treatment costs and losses, reduced freshwater usage, and increased resilience of regional communities. Using CSIRO's triple bottom line impact classification approach, Table 2 summaries the nature of the existing and potential impacts.

Table 2: Impact of Atlantic Salmon Selective Breeding Program

TYPE	CATEGORY	INDICATOR	DESCRIPTION
Economic	Productivity and efficiency	Increase in harvest volume	Salmon from the breeding program demonstrated greater than 10 per cent gains in growth in each generation. This increase in growth equates to production efficiencies worth millions of dollars each year.

Economic	Productivity and efficiency	Reduced treatment cost of AGD	Treatment of AGD is costly and labour intensive. AGD costs the Tasmanian salmon industry approximately 10% of the gross value of production (combination of lost productivity and treatment costs). The project results suggest that there is potential to reduce the frequency of AGD treatment by 25% over approximately 6 years of selective breeding.
Environmental	Aquatic environments	Reduced water consumption	Treatment of AGD requires frequent freshwater bathing to detach the amoeba. The freshwater is in limited supply. Reducing the number of AGD treatments results in a substantial reduction in freshwater consumption.
Social	Resilience	Income and employment	Many of the salmon farming jobs are located in rural areas where there are small populations, limited employment opportunities and high unemployment rates. Increased production by salmon farming companies potentially increases the viability of aquaculture/fishing-dependent communities – especially those with fewer alternative employment opportunities.

Of the benefits identified, economic impacts were estimated in monetary terms, as discussed in the section below. Given the limited availability of data on water consumption and regional employment, environmental and social benefits are noted, but not assessed.

5 Clarifying the Impacts

Counterfactual

While selective breeding programs exist elsewhere in the world, the Tasmanian program is the first to use resistance to AGD as a selection criterion, and was one of the first to use DNA pedigree analyses on mixed families without individual family tanks and identification. The industry could have gone to open market for service providers. However, such a call for a scoping study tender in late 1990s was won by CSIRO, so there is a high probability that any open call would have favoured CSIRO due to its national and international status, proximity to industry and long-term relationship with industry. If CSIRO's involvement and investment in the breeding program had not been made, it is assumed that there would not have been significant breeding research by the private sector or Tasmanian government over this period.

The industry and several research organisations (including CSIRO) had, and still are, investing in treatment alternatives and understanding AGD with nothing to date resulting in commercial gains greater than the breeding work. It is therefore assumed that without CSIRO's involvement and investment in the program, there would have been insignificant genetic improvement of the salmon broodstock and unselected salmon would probably have remained as the primary production stock.

Current commercial gains in terms of reduced costs for managing AGD are unlikely to have occurred without the selective breeding program which provides improved fish which, in turn have helped to generate increased confidence that has encouraged industry to implement additional AGD management strategies.

Attribution

CSIRO was the primary source of research, breeding expertise and resources that underpinned the development of genetically improved salmon broodstock. Other contributors to the successful implementation of CSIRO research include SALTAS, which provided important co-financing from 2005 to 2011. SALTAS has also played an important role in CSIRO's development of improved salmon broodstock by providing stock maintenance and testing facilities. However, SALTAS had a significantly less active role in the research and development components of the work, especially in the early years of the program.

In consultation with SALTAS, we have developed an attribution profile on the percentage of the research impacts that are attributable to CSIRO. The formal technology transfer from CSIRO to SALTAS followed a staged approach, which commenced in 2012 and ended in 2014. From 2014 onwards, SALTAS took the leading role in implementing the technology. As a result, there is a declining contribution attributable to CSIRO and increased contribution attributable to SALTAS.

Table 3: Attribution Profiles

Year	CSIRO (%)	SALTAS (%)
2012	80	20
2013	80	20
2014	75	25
2015	70	30
2016	65	35
2017	60	40
2018	55	45
2019	50	50
2020	45	55
2021	40	60
2022	35	65
2023	30	70
2024	25	75
2025	20	80

Source: CSIRO and SALTAS.

6 Evaluating the Impacts

Cost Benefit Analysis

Definition

This section provides definition of key input costs, benefits and our method of calculating the benefit cost ratio (BCR) in this analysis.

Input costs are the costs incurred by CSIRO and its research partners to produce the research outputs and include costs associated with such things as staff, in-kind contributions, equipment/facilities and background IP. Where data is available, input costs should also include usage and adoptions costs borne by the end users, such as costs of any trials, further development and market tests.

Benefits represent an increase in salmon harvest volume and a reduction in AGD treatment costs. In this analysis, we used industry value added measurement (also called ‘industry gross product’) to monetise the production benefits, which is derived by subtracting production value with costs of goods and services using a 10 year average proportion of value added in the salmon industry.

Therefore, the formula for calculating a benefit cost ratio is defined as a combination of increased industry value added and cost savings benefits (Present Value) divided by all the research, adaptive development and extension costs (Present Value). This ratio can also be interpreted as a “Profitability Ratio” or “Net Benefit/Investment Ratio”.

Time period

While the SBP is an ongoing activity, it is necessary to define a particular period for the cost benefit analysis. Given the history of the project, the analysis is based on research activity since 2005.

In the program, there are lags between DNA genotyping for pedigree assignment and the release of an elite pool of Atlantic salmon broodstock for use by hatcheries. In recent years, the lag has averaged 6 years, so that adoption on farms does not take place until the seventh year after the initial research. On that basis, the benefits are only measured from 2012 onwards. In the analysis, the costs from 2005 are included.

Given the costs are measured until 2011, the benefit must be estimated for the future, since the improved broodstock developed and released before 2011 provide a foundation for production impacts for many years. It is assumed in this analysis that benefits are measured to 2025. CSIRO’s current and growing presence in the salmon industry may owe to the fact that it was one of the earliest providers of cost-effective and environmentally friendly breeding technologies to address the challenge of AGD. However, over time CSIRO’s competitors may have developed similar expertise in the absence of CSIRO. The commercial value of first mover advantage is difficult to determine precisely, but given the lack of equivalent technology available in the salmon industry at the time that CSIRO broodstock was commercialised, we estimate that it would have taken roughly ten years (until 2025) for other researchers to develop similar approaches in the absence of CSIRO.

Thus the analysis involves a component of ex-post analysis (relating to the period 2005-2015), but also involves a large component of ex-ante analysis for the benefits flowing from those activities over the period to 2025.

Costs

Research costs in the CBA had to include all relevant costs that went into developing the new salmon broodstock in Tasmania. In addition to CSIRO's investment, SALTAS investment and in-kind contributions were also critical in providing access to breeding facilities and sea cages, without which the research could not have been undertaken. In our analysis, we distributed SALTAS in-kind contributions (estimated at approximately $0.5 million per annum) over the years from 2005/06 to June 2011/12.

All economic assessment of costs must also recognise the time value of money. Because the CSIRO and SALTAS project dates back to 2005, it was important to first classify costs in real 2015-16 dollars to adjust for inflation. The real (in 2015-16) project costs were then readjusted in present value terms using a discount rate of 7%. This was because any research costs incurred in the past had to be brought forward, as those funds could have been earning interest in the intervening time. Table 4 summarise the adjusted research costs for CSIRO and SALTAS.

Table 4: Summary of CSIRO and SALTAS adjusted program costs

Year	SALTAS (in-kind)	SALTAS (cash)	SALTAS (total)	CSIRO	SALTAS adjusted (2015-16 $)	CSIRO adjsuted (2015-16 $)	Present value of SALTAS costs	Present value of CSIRO costs	Present value of total cost
2005/2006	$247,300	$500,000	$747,300	$200,000	$966,674	$258,711	$1,901,595	$508,924	$2,410,519
2006/2007	$300,000	$500,000	$800,000	$200,000	$1,001,386	$250,346	$1,841,007	$460,252	$2,301,258
2007/2008	$300,000	$500,000	$800,000	$250,000	$973,288	$304,153	$1,672,291	$522,591	$2,194,882
2008/2009	$340,000	$500,000	$840,000	$250,000	$985,455	$293,290	$1,582,425	$470,960	$2,053,384
2009/2010	$340,000	$500,000	$840,000	$253,000	$965,599	$290,829	$1,449,104	$436,456	$1,885,560
2010/2011	$326,000	$500,000	$826,000	$218,000	$924,029	$243,872	$1,295,998	$342,043	$1,638,041
2011/2012	$341,000	$500,000	$841,000	$228,000	$913,471	$247,647	$1,197,374	$324,615	$1,521,989
Total	**$2,194,300**	**$3,500,000**	**$5,694,300**	**$1,599,000**	**$6,729,902**	**$1,888,849**	**$10,939,793**	**$3,065,841**	**$14,005,634**

Source: CSIRO and SALTAS

Benefits to 2025

The benefits calculated in the analysis are the net benefits from the SBP, that is, the difference between the "with" and "without program" scenarios. The analysis is equivalent to carrying out separate analyses for the "with program" and "without program" scenarios and calculating the difference between them.

The steps in quantifying the gains from the program are as follows:

1. Combine the harvest size in each year with the annual rate of improvement in weight due to the program, to get an estimate of the equivalent weight gain for that year. Combine the estimate of weight improvement with annual number of smolts to obtain an estimate of the increase in production that year. This gives an estimate of extra production from the breeding program for that year (and all subsequent years).

2. The gain from the breeding program is converted to 2015 dollars by multiplying by a real price of $13,184/tonne (ABARES)[2]. The same price was used for all years, to ensure that all production is valued equally.
3. Combine the treatment cost in each year with the annual rate of reduction in bathing events required due to the program, to get an estimate of the decrease in AGD treatment costs in that year and all subsequent years.
4. All past benefit flows from 2012 to 2015 are compounded forward to 2015 and the benefits from 2016 to 2025 are discounted back to 2015 at a real discount rate of 7% to convert benefit flows to a present value in 2015.

Increase in Harvest Volume

In Australia, most of the production is Head-on-Gutted (HOG) and therefore HOG is used as a weight measure. The SBP has resulted in increased survival and HOG weight, which helped to increase the value of commercial salmon production. HOG was modelled as % gain in weight at harvest in a set number of days at sea (4.5Kg in 2011 = 6.25Kg in 2025). Values up until 2019 harvest year are derived from existing broodstock. Values for 2020 and beyond assume an average 3% improvement in HOG weight per year. The assumptions and sources for this benefit are outlined in Table 5.

Table 5: Weight gain benefits from the Selective Breeding Program

Measure		Value	Source
With CSIRO research			
A_R	SMOLT inputs (no)	various	Senator Inquiry 2015
B_R	Year class survival rate (%)	88%	CSIRO
C_R	Harvest size (kg)	various	SALTAS modelling
D_R	Average price to farmers (2015 $ per tonne)	13,184 [a]	ABARES
E_R	Proportion of industry value added (%)	18	IBIS
F_R	Annual indicative earnings under target adoption ($)	$=A_R*B_R*C_R*D_R*E_R$	
Counterfactual			
A_c	SMOLT inputs (no)	various	CSIRO
B_c	Year class survival rate (%)	83%	CSIRO
C_c	Harvest size (kg)	4.2	SALTAS
D_c	Average price to farmers ($ per tonne)	13,184	ABARES
E_c	Annual indicative earnings ($)	$=A_c*B_c*C_c*D_c*E_R$	
Impact	World with CSIRO research – counterfactual		
	Value of additional benefits to salmon farmers	$=F_R-E_c$	

Note: ABARES Table17 Aquaculture production in 2009/10–13/14, by state.

[2] an average of the past five years.

Reduction in AGD treatment costs

The SBP has resulted in extension of time between bathing events, which helped to reduce the AGD treatment costs. Reduced bathing frequency is modelled as % extension of time between bathing events (30 days in 2011 = 46 days in 2025). Values of bath frequency from 2012 and 2019 are derived from existing broodstock. From 2020 onwards, we assume an average 4% improvement in AGD bath interval per year. The assumptions and sources for this benefit are outlined in Table 6.

Table 6: Reduction in AGD treatment costs from the SBP Program

Measure		Value	Source
With CSIRO research			
A_R	SMOLT inputs (no)	various	Senator Inquiry 2015
B_R	Year class survival rate (%)	88%	CSIRO
C_R	Interval between bathing events (days)	various	SALTAS modelling
D_R	Improvement in bath interval (%)	various	CSIRO
E_R	Year frequency of freshwater bathing	$=365/ C_R*(1+ D_R)$	
F_R	Average cost of a bathing event (2015 $ per fish)	0.5	CSIRO
G_R	Total treatment costs ($)	$= A_R* B_R* E_R *F_R$	
Counterfactual			
B_c	Year class survival rate (%)	83%	CSIRO
C_c	Interval between bathing events (days)	30	SALTAS modelling
D_c	Year frequency of freshwater bathing	$=365/ C_R*=12$	
E_c	Total treatment cost ($)	$= A_R* B_c* D_c* F_R$	
Impact	World with CSIRO research – counterfactual		
	Value of additional benefits to salmon farmers	$= G_R -E_c$	

Table 7: Analysis of Benefits and Costs of the Selective Breeding Program

Year	Yield Benefits ($)	AGD cost reduction ($)	Total benefits ($)	Present value of benefits ($)	Benefits attributed to CSIRO ($)	Benefits attributed to SALTAS ($)	Present value of total net benefits ($)
2005			-		-	-	- 2,267,132
2006							- 2,156,807
2007							- 2,073,849
2008							- 1,958,026
2009							- 1,781,647
2010							- 1,556,139
2011							- 1,449,375
2012	539,508	- 1,597,034	- 1,057,526	-1,295,515	- 1,036,412	- 259,103	- 1,295,515
2013	2,752,342	- 135,405	2,616,936	2,996,131	2,396,904	599,226	2,996,131
2014	5,527,823	1,549,479	7,077,302	7,572,713	5,679,535	1,893,178	7,572,713
2015	7,808,580	1,969,802	9,778,383	9,778,383	6,844,868	2,933,515	9,778,383
2016	13,032,963	3,117,201	16,150,164	15,093,611	9,810,847	5,282,764	15,093,611
2017	14,277,582	4,785,820	19,063,401	16,650,713	9,990,428	6,660,285	16,650,713
2018	11,142,082	5,323,347	16,465,429	13,440,694	7,392,382	6,048,313	13,440,694
2019	12,697,577	5,723,372	18,420,949	14,053,254	7,026,627	7,026,627	14,053,254
2020	15,434,546	6,386,224	21,820,770	15,557,907	7,001,058	8,556,849	15,557,907
2021	17,499,048	7,256,384	24,755,432	16,495,590	6,598,236	9,897,354	16,495,590
2022	19,697,523	8,131,352	27,828,875	17,330,425	6,065,649	11,264,776	17,330,425
2023	21,969,096	8,976,209	30,945,305	18,010,449	5,403,135	12,607,315	18,010,449
2024	24,315,680	9,828,380	34,144,060	18,572,106	4,643,027	13,929,080	18,572,106
2025	26,739,232	10,671,498	37,410,731	19,017,718	3,803,544	15,214,175	19,017,718
Total	193,433,582	71,986,628	265,420,210	183,274,180	81,619,827	101,654,353	170,031,204

Source: CSIRO

The flows of costs and benefits from 2005 to 2025 are used to calculate investment criteria. Investment criteria was estimated for both total investment and for the CSIRO investment alone, as reported Table 8.

Table 8: Results of Cost Benefit Analysis

Criteria	Program	CSIRO
Present value of costs ($ m)	14.0	3.1
Present value of benefits ($ m)	183.3	81.6
Net Present Value (NPV)	169.3	78.6
Benefit-cost Ratio (BCR)	13	27

Distribution effects on users

Although distribution effects were not considered to be a significant issue, it is worth noting that the majority of the benefits identified accrue to the Tasmanian fish hatcheries and commercial producers of Atlantic salmon. These benefits allow them to either increase production level, or reduce costs for the same level of production.

Externalities or other flow-on effects on non-users

Across all impacts, it is also important to acknowledge that salmon farming has a number of adverse environmental and social impacts. The farming of salmon in inlets and estuaries competes with other activities for the use of coastal waters (such as recreational fishing and boating). Moreover, salmon farming may have adverse effects on nearby property values, because farm structures, excessive noise and the glare of lights may result in a loss of amenity to residential properties on adjacent foreshores. Salmon farming may affect the coastal ecology. Surplus feed and faecal deposits may settle on the seabed, causing changes to the flora and fauna and affecting water quality.

In terms of flow-on effects, some of the benefits assigned to commercial producers of Atlantic salmon will be shared along the input supply and market supply chains, including both domestic and foreign consumers. There may be some potential health benefits to consumers of Australian salmon. For example, Atlantic salmon is a rich and naturally occurring source of omega 3 which has been scientifically shown to help in preventing coronary heart disease, high blood pressure, rheumatoid arthritis and depression. However there are some uncertainties around the magnitude of the health benefits.

7 Sensitivity analysis

While the prospects look promising, the establishment of a fully functioning and sustainable commercial salmon farming sector using CSIRO broodstock is not certain. The take-up of new improved broodstock on a large scale relies on an efficient production and delivery system that is capable of providing good quality, productive broodstock to farmers at reasonable prices. It is also not clear whether new broodstock will deliver the HOG weight benefits in commercial production as modelled.

Given these uncertainties, it would be useful to look at results under different discount, adoption and attribution rates. NPV and benefit cost ratio calculations are particularly sensitive to changes in underlying parameters, so it is important to understand the results in perspective. In this section, we analyse the impact of variations in the discount, adoption and attribution rates as well as the value of salmon prices on benefit and cost streams coming out of our central case. The results of that analysis are shown in Table 9.

Table 9 Results of sensitivity analysis

Assumption	Central assumption	Central Low assumption	High assumption	BCR (low assumption)	BCR (central assumption)	BCR (high assumption)
Discount rate (%)	7	5	10	33	27	20
HOG weight gain due to the Program (%)	Various	10% decrease	10% increase	25	27	28
Average salmon prices to farmers($ per kg)	13,184	10,547	15,821	23	27	31
Benefits of the program attributable to CSIRO (%)	Various	10% decrease	10% increase	24	27	29

While the parameters used in the base-case scenario seemed reasonable in the light of current realities on the ground, it was nevertheless important to test the robustness of our conclusions to variations in these assumptions. The low and high alternative assumptions used in the above sensitivity analysis were brought together to estimate benefit and cost streams under pessimistic and optimistic scenarios by combing changes across all variables jointly. The results under these different assumptions are summarised in Table 10.

Table 10: Alternative assumptions for sensitivity analysis.

	Pessimistic	Central (baseline)	Optimistic
Discount rate (%)	10	7	5
HOG weight gain due to the Program (%)	10% decrease	Various	10% increase
Average salmon prices to farmers($ per kg)	10,547	13,184	15,821
Benefits of the program attributable to CSIRO (%)	10% decrease	Various	10% increase
Benefit cost ratio	19	27	36

The pessimistic and central (baseline) perhaps offered conservative yet realistic forecasts of future benefits. In this we estimated that the benefit cost ratio is between 19 and 27.

8 Limitations and Future Directions

This evaluation is being undertaken using a mixed method to evaluate the research impact arising from the Atlantic Salmon Selective Breeding Program. It combines quantitative and qualitative methods to illustrate the nature of economic, environmental and social impacts. In cases where the impacts can be assessed in monetary terms, a cost-benefit analysis (CBA) is used as a primary tool for evaluation. As a methodology for impact assessment, CBA relies on the use of assumptions and judgments made by the authors. This relates to economic indicators for impact contribution, attribution and counterfactual. These limitations should be considered when interpreting the above analytical results.

Given the scope and budget for the analysis, we acknowledge that there are some limitations with regard to the evidence base of impacts. For example, increase in harvest volume was based on estimates and we had limited knowledge about actual gains over time due to commercial confidentiality. In addition, reduced adverse environmental impacts, protection of employment and increased sustainability of rural communities were not quantified but treated as potential impacts due to the lack of reliable data.

We understand that research impact evaluation is an evolving practice and suggest that as part of its evolution, it needs to address some key data constraints by planning for impact and monitoring progress towards it. It is also important to engage with customers and other stakeholders to collect data and information during the project's lifetime, and to ensure a robust and thorough investigation of all the triple-bottom line outcomes and impacts.

9 References

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FOR FURTHER INFORMATION

Strategy, Market Vision and Innovation
Dr Anne-Maree Dowd
Executive Manager
t +61 7 3327 4468
e anne-maree.dowd@csiro.au
w http://my.csiro.au/impact

CONTACT US

t 1300 363 400
+61 3 9545 2176
e enquiries@csiro.au
w www.csiro.au