FINAL

An Impact Assessment FRDC Investment in 2009-710: Bioeconomic Evaluation of Commercial Scale Stock Enhancement in Abalone

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An Impact Assessment FRDC Investment in 2009-710: Bioeconomic Evaluation of Commercial Scale Stock Enhancement in Abalone
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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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Brad Adams, Chief Executive Officer, Ocean Grown Abalone

Abbreviations

AGV	Abalone Ganglioneuritis Virus
CRC	(Seafood) Cooperative Research Centre
CRRDC	Council of Rural Research and Development Corporations
DAWR	Australian Government Department of Agriculture and Water Resources
DoFWA	Department of Fisheries, Western Australia
FRDC	Fisheries Research and Development Corporation
PVB	Present Value of Benefits
RD&E	Research Development and Extension
WA	Western Australia
WAAIA	Western Australian Abalone Industry Association

Executive Summary

What the report is about

This report presents the results of an impact assessment of a Fisheries Research and Development Corporation (FRDC) and Seafood CRC investment in the economics of commercial scale abalone stock enhancement. The project was funded by FRDC, the Seafood CRC, the Department of Fisheries, Western Australia (DoFWA) and industry over the period October 2009 to June 2016.

Methodology

The project was analysed qualitatively within a logical framework that included activities/outputs, outcomes and impacts. Impacts were categorised into a triple bottom line framework. Principal impacts 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 dollar terms were discounted to the year 2016/17 using a discount rate of 5% to estimate the investment criteria.

Results/key findings

The major impacts identified were of a financial nature and included quicker recovery of abalone populations and fisher profit in areas affected by either an unforeseen disease or overfishing, as well as potential profit associated with abalone sea ranching. Environmental and social impacts were also identified but not valued. It is expected that the Western Australian commercial abalone industry will be the primary beneficiary of the investment.

Investment Criteria

Total funding from all sources for the project was $0.73 million (present value terms). The value of benefits was estimated at $1.70 million (present value terms). This gave an estimated net present value of $0.97 million, and a benefit-cost ratio of 2.3 to 1.

Conclusions

Investment in this project has provided techniques that will allow industry to recover decimated abalone production areas in the event of an unforeseen disease or areas that have been overfished. The project has provided technical assistance for the development of abalone sea ranching in Australia. New knowledge has been garnered as a result of FRDC's investment. However, successful stock enhancement and sea ranching of abalone has been achieved in South East Asia and New Zealand. Overseas based technology therefore may be adapted to Australian conditions. For this reason, the benefit-cost ratios are relatively modest.

Keywords

Impact assessment, abalone, stock enhancement, population recovery, sea ranching, abalone seeding, carrying capacity, bioeconomic model, procedural manual, genomics, population genetic structure, risk management protocol.

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 2009-710: *Bioeconomic Evaluation of Commercial Scale Stock Enhancement in Abalone* 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

Seeding of hatchery-produced marine animals into productive fisheries, known as stock enhancement, is increasingly recognised as a novel management strategy to increase the economic yield of a fishery. It is particularly relevant to sedentary shellfish such as abalone.

The theoretical underpinning of the strategy is that the carrying capacity of fish stocks is rarely reached and that stock enhancement can increase the biomass of a fishery. Stock enhancement has the potential to increase the profitability of a fishery without decreasing allowable catch. Longer term, stock enhancement potentially can increase the fish stock towards virgin levels, increase catch rates, fishing efficiency and fisher profitability.

In 2004 and 2006 the Department of Fisheries Western Australia (DoFWA) and the Western Australian Abalone Industry Association (WAAIA) commenced large scale Greenlip Abalone (*Haliotis laevigata*) stock enhancement field trials with a view to WAAIA commercialising the stock enhancement operation if it was economically viable.

As a consequence, a project was required to collect objective data on the stock enhancement trial (abalone growth and survival rates and the ecological impacts of stock enhancement) and determine the economic return from this activity.

The project builds on previous technical and preliminary economic assessment research completed by DoFWA (Hart et al 2007) and the NSW Department of Primary Industries (Heasman 2006, Allan 2009) as well as the knowledge that abalone stock enhancement is economically viable in New Zealand.

Rationale

Stock enhancement is technically possible. However, there was a need to provide conclusive evidence on whether there was an economic return from stocking wild habitats with juvenile abalone i.e. whether the benefit of additional catch exceeds the cost of stock enhancement.

Prior to this project, most stock enhancement work had focussed on small scale short-term field studies and desk top analyses. This project was based on a long-term field study which delivered accurate economic data, allowed for the completion of comprehensive bioeconomic modelling and enabled a commercial-scale evaluation of abalone stock enhancement to be undertaken.

Project Details

Summary

Project Code: 2009-710

Title: *Bioeconomic Evaluation of Commercial Scale Stock Enhancement in Abalone*

Research Organisation: Department of Fisheries, Western Australia (WA).

Principal Investigator: Anthony Hart.

Period of Funding: October 2009 to June 2016.

Objectives

The objectives of the project were:

1. To estimate long term growth and survival of enhanced Greenlip Abalone.
2. To undertake bioeconomic analysis of large scale stock enhancement in Greenlip Abalone.
3. To evaluate appropriate wild-stock management protocols that facilitate stock enhancement.
4. To develop biosecurity protocols for stock enhancement.
5. To research and develop a commercial-scale stock enhancement manual.

Logical Framework

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

Table 1: Logical Framework for Project 2009-710

Activities and Outputs	• Appointment of a project steering committee and completion of detailed project design. Steering committee included researchers from other states to ensure there was no duplication of effort and the project took full account of past research. The project was completed in partnership with WAAIA and included representation from the New Zealand Paua (Abalone) Enhancement Company. • Release of hatchery-reared juvenile abalone at 25 sites each with three release points. Abalone monitored at six monthly intervals for five years. • DNA profiling and gene sequencing of the WA Greenlip Abalone population and an analysis of genetic diversity and population connectivity. Genetic analysis showed that there are five distinctive adaptive groups of Greenlip Abalone that need to be considered when managing the WA population. • Development of wild stock management protocols that facilitate stock enhancement. Wild stock management protocols addressed (1) spatial and temporal enhancement targets; (2) the effect of enhancement on the genetic structure of the existing wild stock; and (3) the establishment of biological targets as independent measures of the effect of enhancement. The output from this activity was a technical manual that standardised the transport and release protocols for abalone stock enhancement. The technical manual facilitates the training of individuals and commercial-scale rollout of abalone stock enhancement across Australia. • Preparation of biosecurity protocols for stock enhancement. Protocols developed to minimise the risk of disease, the environmental impact of stock enhancement and the goal of maintaining the genetic diversity of the wild stock. Protocols included

	explicit requirements around male and female mating combinations, rotational selection of broodstock, the requirement that only first generation individuals be used for seeding, protocols for the use of sterile individuals, quarantine requirements, equipment cleaning protocols and mandatory disease testing for hatchery-produced abalone released to the wild. The output was a published risk assessment (i.e. Jones and Fletcher 2012). • Bioeconomic analysis using the 'Enhance Fish' model developed by Imperial College London. Model combined population dynamics and fishery information (growth, mortality, stock-recruitment and size-at-maturity), stock enhancement data (size at release, density of release and cost of enhancement) and economic data (abalone beach price, total harvest and fishing cost). The 'Enhance Fish' model showed that abalone stock enhancement was economically viable. • A commercialisation plan that included a blueprint for establishment of a stock enhancement company with abalone culture and enhancement targets. • A DoFWA policy addressing abalone stock enhancement as a management strategy (DoFWA 2013). • Scientific papers and conference presentations describing project results. • A non-technical summary of research findings for public dissemination.
Outcomes	• Availability of management protocols to assist in the recovery of wild abalone stocks following a catastrophic population collapse. • Availability and use of a technical manual to assist with the development of abalone sea ranches. • An established and commercially viable abalone sea ranch in WA. • Availability of biosecurity protocols for the roll out of stock enhancement should industry decide that this is a safe practice. NB: stock enhancement was not an outcome of this project as industry decided that the biosecurity risk was unacceptable e.g. the perceived risk of introducing Abalone Ganglioneuritis Virus (AGV) a herpes-like-virus present in Victoria and Tasmania. • Research capacity that could be used in the future to assist with the management of other WA fisheries e.g. assessment of carrying capacities and the setting of catch limits.
Impacts	• Potential for increased abalone fisher profits from quicker recovery of abalone populations in wild catch fisheries affected by either an unforeseen disease or overfishing. • Profit associated with abalone sea ranching. • Potential increased profit from additional catch in existing abalone wild catch fisheries if stock enhancement is supported by industry in the future. • Reduced risk of overfishing in abalone fisheries with improved knowledge of abalone ecology and carrying capacity knowledge. • Enhanced research capacity with additional DoFWA marine science and economic impact assessment skills. • Potentially increased regional income associated with quicker recovery of abalone populations affected by disease/overfishing, with existing sea ranching and any potential future catch from wild catch fisheries linked to stock enhancement.

Project Investment

Nominal Investment

Table 2 shows the annual investment for the project funded by FRDC, Seafood CRC, DoFWA and other investors. Other investment included contributions made by industry.

Table 2: Annual Investment in Project 2009-710 (nominal $)

Year ended 30th June	FRDC ($)	Seafood CRC ($)	DoFWA ($)	OTHER ($)	TOTAL ($)
2010	0	0	85,425	21,000	106,425
2011	58,174	23,761	87,738	21,000	190,673
2012	37,487	15,311	65,888	21,000	139,686
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	35,756	14,605	0	0	50,361
2016	17,279	7,057	0	0	24,336
Totals	148,695	60,735	239,051	63,000	511,481

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. A multiplier of 1.083 was applied to the Seafood CRC funding.

For the DoFWA and other investment, the management and administration costs for the project are already built into the nominal amounts shown in Table 2.

Real Investment and Extension Costs

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

Impacts

Table 3 provides a summary of the principal types of impacts categorised into economic, environmental and social impacts.

Table 3: Triple Bottom Line Categories of Impacts from Abalone Stock Enhancement

Economic	• Potential for increased abalone fisher profits from quicker recovery of abalone populations in wild catch fisheries affected by either an unforeseen disease or overfishing. • Profit associated with abalone sea ranching. • Potential increased profit from additional catch in existing abalone wild catch fisheries if stock enhancement is supported by industry in the future.
Environmental	• Reduced risk of overfishing in abalone fisheries with improved knowledge of abalone ecology and carrying capacity knowledge. • More rapid recovery of wild abalone populations affected by disease or overfishing.
Social	• Enhanced research capacity with additional DoFWA marine science and economic impact assessment skills. • Potentially increased regional income associated with quicker recovery of abalone populations affected by disease/overfishing, with existing sea ranching and any potential future catch from wild fisheries linked to stock enhancement.

Public versus Private Impacts

Key impacts identified in this evaluation are industry related (increased profit from sea ranching and potential for quicker recovery of fisher profit in wild catch fisheries). Public impacts include the potential for improved environmental outcomes (wild abalone population recovery and reduced risk of overfishing) as well as social impacts (enhanced research capacity and increased regional incomes).

Distribution of Private Impacts

The benefits from sea ranching and potential for quicker recovery of fisher profit will be captured by the commercial sector of the abalone industry. This would include wild abalone fishers, sea ranch operators, processors, abalone wholesalers and exporters who will all share the impacts and potential impacts produced by the project.

Impacts on other Australian Industries

Impacts on industries other than the commercial abalone industry and its associated sectors may include potential gains to other industries via any spillovers from the increases in research capacity e.g. application of bioeconomic modelling.

Impacts Overseas

Overseas impacts will include potential adoption of stock enhancement techniques developed as part of this project.

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. Investment in abalone stock enhancement contributes to Rural RD&E Priority 1, 2 and 3 and to Science and Research Priority 1.

Table 4: Australian Government Research Priorities

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

Sources: DAWR (2015) and OCS (2015)

Valuation of Impacts

Impacts Valued

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

Two impacts were valued. The first was quicker recovery of abalone populations and fisher profit in areas affected by either an unforeseen disease or overfishing. The second was profit associated with abalone sea ranching.

Impacts Not Valued

The economic impact identified but not valued included:

- Potential increased profit from additional catch in existing abalone wild catch fisheries if stock enhancement is supported by industry in the future. Stakeholders contacted indicated that this was unlikely to occur.

The environmental impacts identified but not valued included:

- Reduced risk of overfishing in abalone fisheries with improved knowledge of abalone ecology and carrying capacity knowledge. This impact was not valued due to difficulty in quantifying the causal relationship between additional knowledge and the reduced overfishing risk.
- More rapid recovery of wild abalone populations affected by disease or overfishing. The impact was not valued due to an absence of data describing ecological gains from earlier replacement of abalone populations.

The social impacts identified but not valued included:

- Enhanced research capacity with additional DoFWA marine science and economic impact assessment skills. This impact was not valued because data were not readily available on applications of the additional skills.
- Potentially increased regional income associated with quicker recovery of abalone populations affected by disease/overfishing, sea ranching and any potential future catch from wild fisheries linked to stock enhancement. This impact was not valued due to time and resource constraints.

Valuation of Benefit 1: Quicker Recovery in Abalone Populations and Fisher Profit Following an Unforeseen Disease Event or Overfishing

An important benefit from Project 2009-710 '*Bioeconomic Evaluation of Commercial Scale Stock Enhancement in Abalone*' will be an insurance that the wild catch abalone industry can regenerate an area affected by an unforeseen disease outbreak or an area that has been affected by overfishing. The benefit is relevant to Greenlip Abalone fisheries in WA, South Australia, Victoria and Tasmania.

Wild abalone populations affected by catastrophic disease or overfishing can take up to 40 years to recover to the point where commercial fishing is once again profitable. Supplementation of wild populations with hatchery raised abalone, using techniques developed in this project, will hasten population recovery.

It is assumed that stock enhancement is acceptable to commercial fishers in an area where there is no longer a viable abalone catch.

To quantify the benefit of quicker recovery in abalone populations, it is assumed that a collapsed fishery is identified in 2018 and that historically this fishery accounted for 64,000 kg of wild caught Greenlip Abalone. Greenlip Abalone is the species on which the research project has focussed and a catch loss of this magnitude is equivalent to 10% of total Australian take for that species (Brad Adams, CEO, Ocean Grown Abalone, pers. comm. May 2017).

Hatchery raised stock are released into the collapsed fishery at two years of age and a further two years is required before commercial fishing can re-commence. The first catch from the recovered fishery would be available in 2022 (Brad Adams, CEO, Ocean Grown Abalone, pers. comm. May 2017).

The benefit of quicker recovery in abalone populations is the income earned by fishers from 2022 until Project 2009-710 technology is replaced or the fishery naturally regenerates. Income from earlier recovery of the fishery is estimated at $36/kg of abalone caught less hatchery, stocking, monitoring and catch costs of $22/kg i.e. $14/kg live weight (Hart and Strain 2015).

Specific assumptions for valuing Benefit 1 are provided in Table 5.

Valuation of Benefit 2: Profits from Sea Ranching Abalone

In addition to quicker recovery of depleted wild stocks, the project has contributed to the development of an abalone sea ranch in Flinders Bay, WA (Fish Magazine, December 2012).

The sea ranch uses stock enhancement techniques developed as part of Project 2009-710 to introduce hatchery raised juvenile abalone onto artificial reefs. “If there were rocks on the ocean floor in this area there would be abundant abalone growing on them naturally. All we are doing is putting the rocks down” (Brad Adams, CEO, Ocean Grown Abalone, Fish Magazine, December 2012).

“In the ocean, there are no feed costs and no power costs. Labour is minimal because we don’t have to clean the facility and the only predator so far is the occasional octopus” (Brad Adams, CEO, Ocean Grown Abalone, Fish Magazine, December 2012).

The sea ranch’s first harvest is expected to yield 12,000 kg of Greenlip Abalone (Brad Adams, CEO, Ocean Grown Abalone, pers. comm. May 2017).

Profit attributable to sea ranched abalone has been estimated at $12/kg rather than the $14/kg attributed to wild caught stocks. A lower profit has been assumed as sea ranching might not be able to capture the full premium available in export markets for wild caught (in 2017 the market is still untested) plus a significant allowance has been made for sea ranching capital cost including purpose built artificial reefs and their seeding.

Specific assumptions for valuing Benefit 2 are provided in Table 5.

Counterfactual

If this project had not been funded, it is assumed that techniques for wild stock recovery and sea ranching are introduced from overseas in 2027 and over the following four years application of Project 2009-710 technology is phased out. Phasing out of project 2009-710 technology affects both Benefit 1 and Benefit 2.

Attribution

A raft of previous FRDC and private sector research, together with the current project, has led to the commercial viability of abalone restocking with hatchery raised individuals and the commercial viability of sea ranching. In recognition of the preceding research only 30% of the quantified benefit has been attributed to Project 2009-710.

Summary of Assumptions

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

Table 5: Summary of Assumptions

Variable	Assumption	Source/comment
COUNTERFACTUAL: Techniques for wild stock recovery and sea ranching are introduced from overseas in 2027 and over the following four years application of Project 2009-710 technology is phased out.		
Benefit 1: Quicker recovery in abalone populations and profit following an unforeseen disease event or overfishing		
Annual Australian Greenlip Abalone catch, live weight.	640,000 kg	Brad Adams, CEO, Ocean Grown Abalone, pers. comm. May 2017.
Historical annual production assumed from a collapsed Greenlip Abalone fishery.	64,000 kg	10% of total Australian catch (Brad Adams, CEO, Ocean Grown Abalone, pers. comm. May 2017).
Assumed year of fishery collapse	2018	Consultant assumption
Time taken for natural recovery of production from the collapsed fishery	Up to 40 years	Nicole Stubing, Project Manager, FRDC pers. comm. May 2017
Year in which population recovery commences using hatchery produced juveniles and project generated technology.	2018	Two years after Project 2009-710 completion. NB: if this was a disease affected stock a longer lapsed time might be appropriate to allow for disease attenuation. Alternatively, disease resistant stock may be used.
Year in which first recovered population harvest occurs.	2022	Two years to grow 100 mm hatchery stock plus two years to mature stock in depleted habitat (Brad Adams, CEO, Ocean Grown Abalone, pers. comm. May 2017).
Ramp up in harvest from the recovered population and decline in benefit when overseas technology replaces impacts from Project 2009-710.	2022 = 16,000 kg 2023 = 32,000 kg 2024 = 48,000 kg 2025 = 64,000 kg 2026 = 64,000 kg 2027 = 64,000 kg 2028 = 48,000 kg 2029 = 32,000 kg 2030 = 16,000 kg	Consultant assumption after review of relevant literature.

Price received by fishers for wild caught abalone.	$36/kg live weight.	Hart and Strain 2015 and confirmed in ABARES 2016
Cost of hatchery, stocking, monitoring and catch.	$22/kg live weight.	Hart and Strain 2015.
Profit generated from recovered abalone catch.	$14/kg live weight.	Price of $36/kg less fishing and other costs of $22/kg.
Benefit 2: Profits from Sea Ranching Abalone		
Yield from sea ranching Greenlip Abalone in WA	2018: 12,000 kg	Brad Adams, CEO, Ocean Grown Abalone, pers. comm. May 2017.
Ramp up in yield from sea ranching and decline in benefit when overseas technology replaces impacts from Project 2009-710.	2018 = 12,000 kg 2019 = 14,000 kg 2020 = 16,000 kg 2021 = 18,000 kg 2022 = 20,000 kg 2023 = 22,000 kg 2024 = 24,000 kg 2025 = 26,000 kg 2026 = 28,000 kg 2027 = 30,000 kg 2028 = 22,500 kg 2029 = 15,000 kg 2030 = 7,500 kg	Consultant assumption after review of relevant literature.
Profit from sea ranching	$12/kg live weight	Consultant assumption – a lower premium than wild catch plus seeding costs and an allowance for annualised capital costs for purpose built artificial reefs.
Attribution		
Attribution of the above benefits to this project	30%	Consultant assumption based on previous FRDC and private sector work on abalone restocking.

Results

All benefits after 2016/17 were expressed in 2016/17 dollar terms. All costs and benefits were discounted to 2016/17 using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the Modified Internal Rate of Return. The base analysis used the best available estimates for each variable, notwithstanding a level of uncertainty for many of the estimates. All analyses ran for the length of the project investment period plus 30 years from the last year of Project 2009-710 investment (2015/16).

Investment Criteria

Tables 6 and 7 show the investment criteria estimated for different periods of benefits for the total investment and the FRDC investment. The present value of benefits (PVB) attributable to FRDC investment only, shown in Table 7, has been estimated by multiplying the total PVB by the FRDC proportion of real investment (31%). The balance of benefits is attributable to the Seafood CRC, DoFWA and other project contributors (e.g. WAAIA).

Table 6: Investment Criteria for Total Investment in Project 2009-710

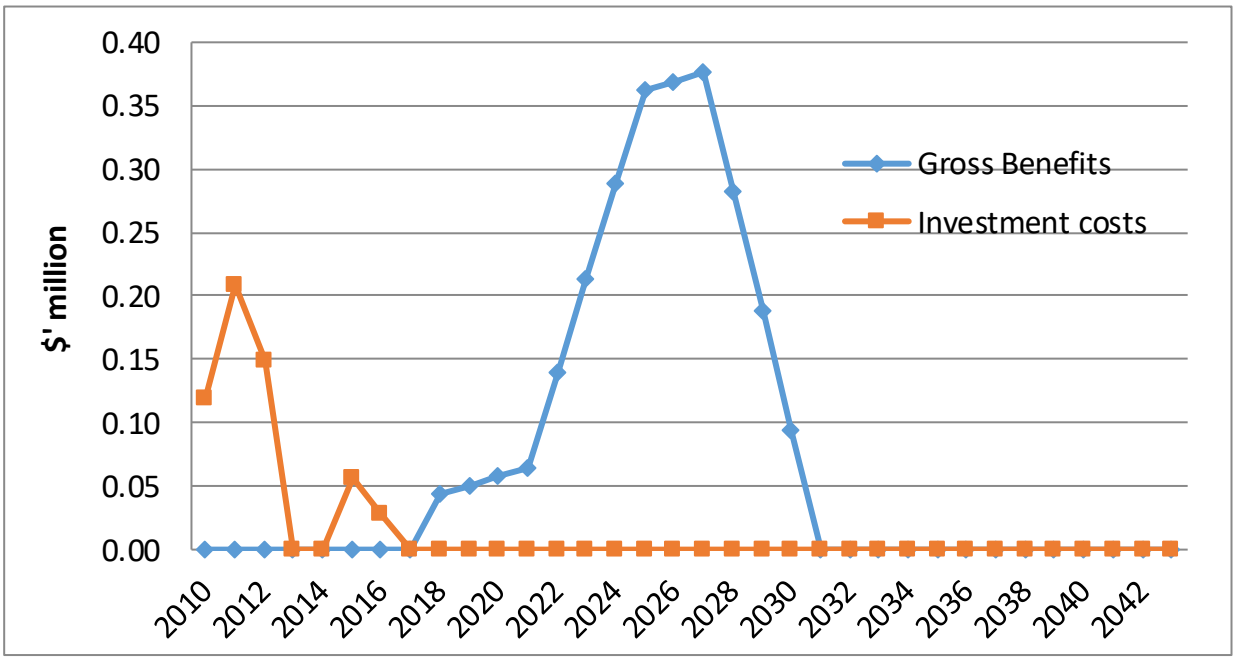
Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	0.19	1.15	1.70	1.70	1.70	1.70
Present value of costs ($m)	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Net present value ($m)	-0.73	-0.54	0.42	0.97	0.97	0.97	0.97
Benefit-cost ratio	0.00	0.26	1.57	2.33	2.33	2.33	2.33
Internal Rate of Return (IRR) (%)	negative	negative	9.05	11.92	11.92	11.92	11.92
Modified IRR (%)	negative	negative	10.42	11.54	9.78	8.77	8.11

Table 7: Investment Criteria for FRDC Investment in Project 2009-710

Investment criteria	**Number of years from year of last investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits ($m)	0.00	0.06	0.35	0.52	0.52	0.52	0.52
Present value of costs ($m)	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Net present value ($m)	-0.21	-0.15	0.14	0.31	0.31	0.31	0.31
Benefit-cost ratio	0.00	0.27	1.65	2.45	2.45	2.45	2.45
Internal Rate of Return (IRR) (%)	negative	negative	9.95	12.99	12.99	12.99	12.99
Modified IRR (%)	negative	negative	11.05	11.94	10.07	9.00	8.30

The annual undiscounted benefit and cost cash flows for the total investment for the duration of Project 2009-710 investment plus 30 years from the last year of Project 2009-710 investment are shown in Figure 1.

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



Source of Benefits

Estimates of the relative contribution of each benefit valued, given the assumptions made are shown in Table 8.

Table 8: Contribution to Total Benefits from Each Source

Source of Benefits	**Contribution to PVB ($m)**	**Share of Benefits (%)**
Benefit 1: Quicker recovery in abalone populations and profit following an unforeseen disease event or overfishing	1.04	61.5
Benefit 2: Profits from Sea ranching abalone	0.65	38.5
Total	1.70	100.0

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 in Project 2009-710. All other parameters were held at their base values. Table 9 presents the results. Results are not overly sensitive to the discount rate employed.

Table 9: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($m)	2.53	1.70	1.18
Present value of costs ($m)	0.56	0.73	0.94
Net present value ($m)	1.97	0.97	0.24
Benefit-cost ratio	4.51	2.33	1.26

Impact assessment results are dominated by Benefit 1 'Quicker recovery in abalone populations and profit following an unforeseen disease event or overfishing' (see Table 8). Consequently, two further sets of sensitivity analyses were completed on Benefit 1 while leaving the contribution made by Benefit 2 unchanged. The first tests the volume of recovered abalone catch (Table 10) and the second tests profits received on the recovered catch (Table 11).

The volume of recovered catch in each year was sensitivity tested assuming the catch increase was only half and one quarter that recorded under the base analysis (Table 5). Even at one quarter the recovered catch, the project still returns a positive benefit-cost ratio of 1.25 (Table 10).

Table 10: Sensitivity to Recovered Abalone Catch
(Total investment, 30 years)

Investment Criteria	**Recovered Abalone Catch**		
	Quarter Base	**Half Base**	**Base**
Present value of benefits ($m)	0.91	1.18	1.70
Present value of costs ($m)	0.73	0.73	0.73
Net present value ($m)	0.19	0.45	0.97
Benefit-cost ratio	1.25	1.61	2.33

The second sensitivity analysis on Benefit 1 addresses the assumption on the profit generated from the recovered abalone catch while leaving the contribution made by Benefit 2 unchanged. Even at a profit of $2/kg, the project returns a positive benefit-cost ratio of 1.10 (Table 11).

Table 11: Sensitivity to Profit Generated on Recovered Abalone Catch
(Total investment, 30 years)

Investment Criteria	**Recovered Abalone Catch**		
	$2/kg	**$5/kg**	**$14/kg Base**
Present value of benefits ($m)	0.80	1.03	1.70
Present value of costs ($m)	0.73	0.73	0.73
Net present value ($m)	0.07	0.30	0.97
Benefit-cost ratio	1.10	1.41	2.33

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 12). 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 12: Confidence in Analysis of Project

Coverage of Benefits	**Confidence in Assumptions**
High	Medium

Coverage of benefits was assessed as high. The two most important benefits (quicker recovery of abalone populations and sea ranching) were valued.

Confidence in assumptions was rated as medium. Principal assumptions around quantification of a collapsed abalone population were hypothetical but were based on a real situation (AVG in Victoria) and were prepared in consultation with Brad Adams of Ocean Grown Abalone. Brad is a Western Australian abalone sea ranching pioneer.

Conclusions

Investment in this project has provided techniques that will allow industry to recover decimated abalone production areas in the event of an unforeseen disease or areas that have been overfished. The project has provided technical assistance for the development of abalone sea ranching in Australia. New knowledge has been garnered as a result of the investment. However, successful stock enhancement and sea ranching of abalone has been achieved in South East Asia and New Zealand. Overseas based technology therefore may be adapted to Australian conditions. For this reason, the benefit-cost ratios are relatively modest.

Investment in this project totalled $0.73 million (present value terms) and produced aggregate total expected benefits of $1.70 million (present value terms). This gave a net present value of $0.97 million, a benefit-cost ratio of 2.3 to 1, an internal rate of return of 11.9% and a modified internal rate of return of 8.1%.

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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